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Ditton Corner on the main London—Maidstone Road (with Red Lamp Danger Signal) is the turning to the Research Station for visitors coming by road.

Telephones; The Station is now served by two lines:
Research Station, *Administrative*—(Aylesford 7229).
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Section I

Pomology

THE ELIMINATION OF SOURCES OF ERROR IN FIELD EXPERIMENTS.

THE STANDARDIZATION OF FRUIT TREE STOCKS.

By R. G. HATTON.

When the pioneer of research in fruit growing attempted to apply the teaching and methods of science to horticulture, his avowed object was " to ascertain by direct trial the true behaviour of the subjects in question under given circumstances, instead of accepting the generally held beliefs and the rule of thumb methods of former generations " (1). However, the field for exploration was all too wide for a single generation. Some generally held beliefs had to be accepted, and Pickering chose to take his material for granted and to accept the established traditions of the nursery trade with, for instance, its dwarf apples on " the Paradise Stock " and its vigorous ones upon " the Crab. " Pickering's problems differed from those of the amateur experimenters of former generations, whose intensive study of the responses of a single tree to varied treatments had established its training and regulation as a fine art. Pickering chose commercial fruit growing as his purview and set out to tell the fruit grower what would be the responses of the " average tree " in the orchard and plantation under given sets of circumstances. In so doing, it was necessary for the first time to think in numbers, varietal differences, cycles of years, variations of site and soil, all of which it was realized were disturbing factors, at any rate to some extent, in militating against the decisive answers which were being sought. In 1911 (2) and again in his final summary in 1919 (1), Pickering enumerated these and many other sources of error which do not generally affect experiments in agriculture, where for the most part annual harvestings of frequent replications of plots each comprising a large number of plants yield the result. The length of time taken by the tree to reach maturity, the common habit of bearing in alternate years thereafter, the cumulative effect of certain inevitable treatments, the legacies from past seasons, the comparatively wide spaces required and the consequent soil variation on large plots, are but some of the difficulties which the horticultural investigator has to face. Again, the limited type of record which it is possible to take upon plants which cannot be lifted and weighed annually and which grow to large proportions, add to his problems.

Pickering tried to take a general measure of this variability, and hence of the experimental error in horticultural work, upon what he thought to be " similar trees under the same conditions," but since he never questioned the origin and " build up " of his material there is no real basis for comparison

betwixt his figures expressing the range of variability amongst individual trees with those more recently derived from trees of which the history of both graft and rootstock is known plus a process of standardization. It is clear that he found " enormous " variation in the cropping of anything but mature trees (i.e. eighteen years), even on " the Paradise " stock, at which age in a single year he calculated the probable error of the mean for six adjacent trees as ±7.1 per cent.

He quoted an approximately similar figure for the probable error for other observations such as the measurement of the tree's girth and annual wood increments, and eventually advised the use of plots of six or eight contiguous trees as a suitable experimental unit (2).

Yet many of the simple issues in the field which he set himself to unravel, such as the effect of a balanced fertilizer compared with the withholding of all manure, remained unanswered at any rate to the satisfaction of practical horticulturists. How far this was due to methods of technique, to variability in material and to a combination of all the other uncontrollable factors has never been shown. Although, unfortunately, it is impossible to make any strict comparison between this material and the standardized trees growing on true Broad-leaved Paradise No. 1 at East Malling, it is significant that the cropping behaviour of trees of the same variety in their first full cropping year (i.e. the tenth), although placed in widely separated locations showed for eight trees a probable error of ±4.6 (by which it is possible to prove a difference of 21 per cent. between two means). This example is representative of the behaviour of the same variety on a number of similar clonal rootstocks, so that in the light of Pickering's experience it would seem that the standardized material shows considerably less variability.

It is instructive to turn from these experiences to those of American horticulturists, and to follow their findings in similar field trials.

Chandler, in his masterly summary of " how the best orchard practices are learned," frankly admits that field experiments have been disappointing in yielding conclusive results unless it be in the sphere of orchard spraying trials (3). Almost contemporaneously with Pickering, the pomologists at the Geneva Experiment Station, New York, laid out a series of fertilizer trials with apples, under conditions which led those in charge of the work to look confidently for some results. Yet after twenty-seven years " manure did not cause an appreciable increase in yield or growth," the results being " too irregular and the increases too small to show any certain financial benefit " (4). In order to check these results, a much more extensive experiment was laid out in various parts of the State but, after a seven years' run, it was reported that " the tree variability factor together with the small populations which had to be used were not the least important in contributing to the results " which were again

disappointing in yielding no decisive answers (5). The evidence for the failure of field trials is even more strongly presented by Anthony and Waring who state that " the past twenty-five years cover an era of fertilizer field trials, yet the returns have been so meagre that they have served to bring discredit upon this type of experimentation." After holding up to critical examination the data collected on a wide range of such projects, they conclude " we must reduce the variability of our material and we must have larger numbers under each treatment," and again, " we must remove what is probably the chief cause of orchard variation, the seedling root. We must develop uniform rootstocks that are asexually propagated " (6).

With the idea of attempting to eliminate the possible sources of error one by one, East Malling started in 1912-13 to find out what " the Paradise," or vegetatively raised rootstock in commercial use for bush apples really was, and how and why it dwarfed the tree in contrast to " the Crab stock," a heterogeneous collection of seedling material which was always supposed to produce more vigorous trees. It is now well known that a careful examination and botanical description of " the Paradise stock " revealed some nine distinguishable varieties of layered rootstocks in fairly common circulation in Europe, and a further eight in course of introduction. They were badly intermixed and misnamed (7). However, because they were all raised vegetatively, i.e. by layers or cuttings, they were traditionally supposed to remain surface rooting and therefore dwarfing. These suppositions have since proved to be fallacies, and do not even bear any correlation with one another. These races of layered (or Paradise) stocks, which had their origin in sexually produced seedlings but their multiplication through asexual methods, were then grafted with named scion varieties to test their comparative suitability for their traditional purpose. The earliest results demonstrated that, even with the somewhat crude methods of plot arrangement then in use, and with a none too standardized nursery and cultural practice, it was possible to show for a single variety, Lane's Prince Albert, four significantly different behaviours as regards size, annual new growth length, fruit bud formation and early cropping of the tree, quite apart from other less measurable but equally obvious characteristics such as habit of growth, quality of fruit and root anchorage. Other factors, such as relative time of blossoming, potentialities for setting that blossom and resistance to pathological troubles and physiological disturbances are also quite definitely affected by rootstock (8).

The trees upon which these records were accumulated are now only ten years old, and instead of being contiguous, each series on a single stock was deliberately scattered in at least four situations, thus courting soil variation, and yet for a single variety upon " the Paradise " stock it has been possible to demonstrate the wide range of behaviour shown in Table I.

TABLE I.

Table showing different growth and cropping of Lane's Prince Albert apple on four different rootstocks.

Stock No.	Total Wood Growth (metres).				Cropping (lbs.).			
	At 7 years old		At 10 years old.		Up to 6th year.		Up to 10th year.	
	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.	Mean.	S.E.
IX	**46.9**	3.6	**136.6**	9.6	**18.0**	1.40	**72.7**	5.2
II	**109.2**	7.8	**388.5**	26.1	**6.0**	0.87	**56.5**	3.4
I	**159.2**	7.4	**548.2**	25.3	**3.6**	0.75	**75.1**	3.8
XII	**233.2**	8.2	**810.4**	27.1	**0.2**	—	**22.7**	1.7

From this table it will be readily perceived that it is possible to show four varieties of rootstock, all of which differ from one another completely in their effects upon the vigour of a single variety of apple.

This is apparent at quite an early stage and becomes accentuated in later years, and it will be seen that, during the first ten years of their lives, the trees on rootstock No. XII have averaged six times the amount of growth that has been made by those on stock No. IX. Yet these are only two varieties of rootstock originally selected for vegetative reproduction from the unlimited seedling population, with which the earlier pioneers were content to work.

Turning to the crop figures, in six years it has been proved quite definitely that there are differences in earliness of bearing. One variety of rootstock has produced trees which have already borne 18 lbs. per tree, while another has, it is true, produced enormous trees but as yet there has been no fruit. At the later period again, trees on one of the intermediate rootstock varieties (No. I) has caught up those on the very precocious No. IX, but the other two still differ significantly from them. These differences in the behaviour of a single variety merely due to its different " build up " are in themselves as great as might be expected from different pruning or fertilizer treatments, yet, with mixed material of this nature and with small numbers of trees, the pioneers were looking for responses which they naturally could not detect. The thought at once arises, if these four vegetatively raised representatives of seedlings cause such different behaviours in the scion, then the behaviour of the same scion worked upon an infinite range of seedlings, every one differing from every other, must be at least many times more variable.

Batchelor and Reed made an extensive study of the variability of yields of many kinds of fruit trees for the purpose of field trials, and it is obvious from the published figures that they met with the high order of variability which other workers have complained of where using seedling rootstocks. Indeed, these

writers were reduced, as Pickering too was, to adopting the expediency of " the not entirely satisfactory " discarding of " abnormal " trees and the substitution of " the average yield of the eight surrounding trees " (9).

It is unfortunate that no strictly comparable plantation of mature trees worked upon rootstocks raised both vegetatively and from seed are in existence from which to secure accurate data as to their comparative variability.

There is, however, a considerable amount of circumstantial evidence to support the *a priori* reasoning which points to the greater variability of trees worked on seedling roots. One extreme instance may be quoted from the pruning plot at East Malling, where a number of fourteen year old Early Victoria apple trees grown upon seedling French Crab and upon trade (and therefore possibly mixed) Paradise, in adjacent rows, can be compared. Although, as one year olds, all the trees had been carefully graded for size, those on seedlings have exhibited at least double the amount of variation in growth and cropping compared with the series on vegetatively raised stocks. Whilst the lightest cropping tree on Crab produced only 146 lbs. of fruit in fourteen years, the heaviest cropping have 1,437 lbs., or ten times as much. These amazing differences in the cropping of the individual trees on " the Crab " demonstrate how economically important the variation in material so raised may be. If a grower had planted one acre of trees on mixed stocks such as these, he would have harvested about 28 tons of fruit in thirteen years. If, through vegetative propagation, he could have standardized his trees to the performance of the four best, he would have harvested over 51 tons, or to that of the behaviour of the four worst, less than 10 tons (10).

It is hardly necessary to stress the importance of this to the horticultural investigator who has to plan experiments in the field.

The greatest difference in the cropping of the same series on " Paradise " was between tree No. 4 giving 174 lbs. and tree No. 1 giving 678 lbs., or about four times as much.

In this series of trees the co-efficient of variability for cropping was 57.1 for the trees on Crab and 36.5 for those on Paradise ; for girth of stem the figures are even more striking, 27.4 as against 12.9.

In the same plantation it has been possible to make further comparisons between trees on the two types of rootstock. Despite the fact that " the Paradise " have in not a few cases now been proved to be mixed, and that certain cultural treatments have tended to accentuate their variability, there is not a single instance where the sets of trees on seedling Crab are more uniform, and a number in which they have proved definitely more variable. In studying one particular feature, that of comparative susceptibility to leaf scorch upon two such parallel series, pruned and unpruned, " it was found that if it were desired to detect a difference of 10 per cent. in the incidence of ' Scorch ' upon two units

of trees, the number of trees necessary in each unit to give a reliable result would be 15 if the trees were on ' Paradise ' stocks, and 420 if on ' Crab ' " (11). Whilst the numbers of observations were dangerously small for making statistical generalizations, the vast difference in the figures thus revealed cannot be neglected by those engaged in fruit tree research.

One further comparison of the behaviour of a single variety upon clonal and seedling rootstocks might be given. In a plantation of six year old Lord Derby apple trees, in units of twelve trees, those on seedling roots are " significantly more variable than those on vegetatively raised stocks, and inspection shows that they are more variable in their habit and type of growth and earliness of leaf-fall as well as in measurable characteristics such as height, spread and girth. The co-efficients of variability based on the girth measurements of the trees on the four clonal rootstocks were 4.3, 3.1, 3.3 and 3.2, whilst those in the two series of trees on seedlings were 6.2 and 11.7 " (12).

Finally, it has been possible within a space of ten years, and with units of only eight trees in two different locations, to demonstrate beyond all doubt the effects of a balanced fertilizer compared with no manuring of apples upon clonal rootstocks. Not only so but, as the accompanying Table II. shows, it has been possible to trace a differential response of the same varieties to the two treatments upon different rootstocks. In other words, a knowledge of the potentialities of the material used for such an experiment is an essential part of its lay-out.

TABLE II.

Effect of Manuring Apples on various Rootstocks reflected in girth measurements in mm.

Bramley on Rootstock No.	1925.*	1927.	1928.	1929.	1930.	
I	217	315	372	410	455	Complete fertilizer.
	221	316	369	414	456	No manure.
IV	218	323	**383**	**433**	**478**	Complete fertilizer.
	215	312	**362**	**401**	**429**	No manure.
V	213	308	**369**	**418**	**475**	Complete fertilizer.
	212	298	**347**	**388**	**433**	No manure.
VII	**193**	287	342	382	**416**	Complete fertilizer.
	209	289	332	364	**386**	No manure.

* The trees were 6 years old in 1925, previous to which date no differences in favour of manuring were shown. Significant differences are shown in block type.

Table II shows how by the eighth year trees of Bramley's Seedling on rootstocks Nos. IV and V were already giving a significant response to manuring,

which by the tenth year had become striking for such a sensitive expression of vigour as girth measurement. It shows, further, that on one rootstock—Broad-leafed Malling No. I, the actual girth increment has not as yet been affected by the withholding of manure, though, as a matter of fact, the rate of increment suggests that this feature will not be long maintained. Trees on rootstock No. VII are only beginning to demonstrate the difference in the tenth year.

TABLE III.

Effect of Manuring Apples on various Rootstocks reflected in Weight or Number of Crop.

Worcester Pearmain on No.	1924.	1925.	1927.	1928.	Total (8 years' crop).	
I	4	7	**35**	**35**	**82**	Complete fertilizer.
	2	7	**21**	**26**	**57**	No manure.
IV	**6**	**8**	**39**	**42**	**98**	Complete fertilizer.
	4	**5**	**23**	**26**	**61**	No manure.
V	1	4	17	26	48	Complete fertilizer.
	0.5	4	15	22	42	No manure.
VII	3	**3**	20	23	50	Complete fertilizer.
	3	**5**	18	21	50	No manure.

Bramley's on No.	Total Nos. to 1927.	lbs. 1928.*	
I	74	**119**	Complete fertilizer.
	53	**64**	No manure.
IV	72	**95**	Complete fertilizer.
	72	**69**	No manure.
V	55	**71**	Complete fertilizer.
	64	**32**	No manure.
VII	85	**114**	Complete fertilizer.
	92	**75**	No manure.

* First full cropping year.

Table III illustrates the same point so far as crop weight is concerned. In the case of Worcester Pearmain the differential response of trees on different rootstocks is shown by the striking response to a complete fertilizer dressing of trees on Nos. I and IV in their seventh and eighth years, as against the absence of evidence of any beneficial effect on those on Nos. V and VII. When the Bramley's Seedling trees bore their first full crop at nine years old, the number, weight, size and quality were in every case poorer on the starved plot. In other words, both scion variety and the sort of rootstock used have definitely qualified the simple answer to the question which it was planned to elucidate, and yet

the experiment, even at such an early date, has clearly enunciated the general principle that the " build up " of the tree is the first fundamental consideration.

It may be admitted that the present generation of pomologists has been fortunate in the elementary nature of many of the initial problems which have fallen to its lot to elucidate, such as the different responses to such treatments as pruning and no pruning, manuring and no manuring and big rootstock differences. However, it can be fairly claimed that the answers have been most clearly given in field experimentation, and those not only for one particular locality but in a form clearly demonstrating general fundamental principles. There is no cause for discouragement, if the differences to be sought in the future are of a lesser order, because the technique of field experimentation, plot planning and record taking have now so far advanced that many of the other sources of variability, such as soil variation, can be eliminated just as the variability in tree individuality has been reduced to reasonable proportions through the use of clonal rootstocks. The size of plots can be brought to much more workable proportions, which in its turn will allow of much more detailed recording. There is still a great harvest to be reaped from the properly designed and executed field experiment with fruit trees.

Summary.

Field experiments with fruit trees have been widely discredited because of the great variability in behaviour of even similarly treated individuals of a single variety. This variability is partly due to external conditions, which modern plot planning is designed to eliminate, but much of the supposed inherent variability has been traced to the influence of mixed seedling rootstocks upon the variety grafted thereon. Standardization of rootstocks, through vegetative propagation, has immensely reduced variability, and so increased the reliability and potentialities of trials. That a single variety of apple responds quite differently in the early years to fertilizer dressings when grafted upon different known rootstocks has been conclusively proved. The " build up " of the tree should be the first fundamental consideration both of the investigator and the grower.

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PEACH STOCK TRIALS.

A Progress Report.

By A. W. WITT and R. J. GARNER.

An investigation upon rootstocks for peaches was begun at this Station in 1921 when some eight stocks in common use for plums were budded with "Hale's Early" peach. From 1921 to 1928 an increased number of varieties of stocks were budded, the units varying from twenty to forty.

The largest selection of stocks used in any one year was budded in 1924. The performance of each stock has been consistent throughout the nursery trials. The stocks may be divided into three groups: (1) stocks in common use for peaches, (2) stocks in common use for plums and (3) clone races of Black Damas selected by this Station. All the stocks mentioned in this paper were fully described by Hatton in 1921 (1).

Table I.

Hale's Early Peach on Rootstocks in common usage for peaches, showing percentage one year old trees obtained and subsequent mortality after planting out.

Stock.	Brompton.	Com. Mussel.	B.L.S. Mussel.	N.L.S. Mussel.	Kroos-jespruim.
No. of Buds inserted 1924	30	23	30	30	20
% Failures	27	26	43	43	15
% dead, end of 1925	Nil.	Nil.	Nil.	Nil.	Nil.
% Maidens produced	73	74	57	57	85
No. of trees planted at East Malling ..	8	8	8	6	6
No. dead 1st year ..	Nil.	Nil.	Nil.	Nil.	Nil.
No. dead 2nd year ..	Nil.	Nil.	Nil.	1	Nil.
No. dead 3rd year ..	Nil.	Nil.	Nil.	Nil.	Nil.
No. dead 4th year ..	Nil.	Nil.	1	Nil.	Nil.

Behaviour in the Nursery.

Table I gives the performance in the nursery of five stocks in common use for peaches. Brompton, Common Mussel and Kroosjespruim have produced a high percentage of maiden trees and of those trees on these three stocks which

were planted out for further trial, none had died. The same remarks do not apply to Broad-leaved Shining Mussel and Narrow-leaved Shining Mussel. Bud failures have been rather less in other years, but the " takes " have not been so consistently good as on other stocks set out in this table. Of the eight trees on Broad-leaved Shining Mussel and the six on Narrow-leaved Shining Mussel planted, one of the latter died in the second and one of the former in the fourth year after planting. Moreover, one of the remaining trees on each of these stocks is distinctly less vigorous than the rest ; this may be an indication of delayed incompatibility. Of the four stocks given in Table II, both Myrobolan B and Common Plum have proved completely incompatible.

TABLE II.

Hale's Early Peach on Rootstocks hitherto generally used as plum stocks, showing percentage one year old trees produced and subsequent mortality in the field.

Stock.	Pershore.	Myrobolan B.	Common Plum.	St. Julien de Toulouse.
No. of buds inserted 1924 ..	**30**	**30**	**20**	**20**
% Failures	23	50	85	20
% dead, end of 1925 ..	Nil.	50	15	Nil.
% Maidens produced ..	77	Nil.	Nil.	80
No. of trees planted at East Malling	**8**	—	—	**6**
No. dead 1st year	Nil.	—	—	4
No. dead 2nd year	Nil.	—	—	—
No. dead 3rd year	Nil.	—	—	—
No. dead 4th year	Nil.	—	—	—

Fifty per cent. of the buds inserted in Myrobolan B failed to grow and the remainder died before the end of the first season ; similarly 85 per cent. failed to grow on Common Plum and all were dead at the end of the season. The performance of the clone Myrobolan B in these trials must not be taken as typical of all Myrobolan seedlings. Howard and Heppner (2) have shown that all ranges of compatibility and incompatibility are found amongst seedlings of this species of rootstock.

The good performance of St. Julien de Toulouse was not maintained ; of six maiden trees planted out at East Malling four died before the end of the first year, again demonstrating delayed incompatibility. The remaining stock, Pershore, has shown no sign of incompatibility.

TABLE III.

Hale's Early Peach on clone rootstocks raised from seedlings of Black Damas, showing percentage one year old trees produced and subsequent mortality in the field.

Stock.	Damas A.	Damas B.	Damas C.	Damas D.
No. of buds inserted 1924	30	14	29	37
% Failures	Nil.	22	4	27
% dead, end of 1925	100	Nil.	Nil.	Nil.
% Maidens produced	Nil.	78	96	73
No. of trees planted at East Malling ..	—	6	10	10
No. dead 1st year	—	Nil.	Nil.	Nil.
No. dead 2nd year	—	Nil.	Nil.	Nil.
No. dead 3rd year	—	Nil.	Nil.	Nil.
No. dead 4th year	—	Nil.	Nil.	Nil.

Table III. gives the nursery performance of four clone races of Black Damas. All the buds on Damas A grew out at the commencement of the season, but died before the following winter. Damas B, C and D have given consistently good results in the trials. Trees on Damas B proved, in later years, to be weaker than those on Damas C or D. A similar story is told by the clone races of St. Julien stocks selected by this Station, St. Julien D showing complete incompatibility and St. Julien C having a dwarfing effect. Unfortunately this last is rather more difficult to propagate than the others.

TREATMENT DURING TRAINING.

A field trial of trees budded in 1924 was planted out in the winter of 1925-26, healthy trees as comparable as possible being selected ; the nursery history of these has just been described.

Pairs of trees were planted in various parts of the plot, but " random distribution " was not adopted.

In the training of the trees the best horticultural practice was followed. During the early years it was found possible to mete out strictly even treatment to the trees, except in the last year when it was essential to use all the available space, training being governed by the vigour and space available for each branch. Immediately after planting, the lateral shoots were cut to basal buds and the main stem was lightly tipped. All buds as they grew were removed except two strong buds approximately twelve inches above ground level. When these two lateral buds had made nine inches of growth, the main stem of the tree was cut

clean out above the buds. The branches were tied out inclined slightly upwards from the horizontal, one on each side of the main stem. During the following winter (1926-27) these branches were cut at approximately seven inches from the main stem. Two branches were allowed to grow from each main branch during the summer of 1927, the lower being cut at twelve inches from the point of origin and the upper at nine inches during the winter of 1927-28. About eight shoots on each side of the main stem were allowed to grow in the summer of 1928, and in the following winter these shoots were cut back to fifteen inches. During the summer of 1929 as many shoots as possible were allowed to grow, the actual number being governed by the space available. The main object in training a peach tree is to obtain as perfect a " fan " as possible. In peach trees it is a common occurrence for branches to die suddenly for no apparent reason. This is apt to leave a gap unless the branches can be raised or depressed without destroying the symmetry of the tree.

Records Taken and General Treatment.

Records were taken of new wood growth, weight of prunings, stem girths and, in the final year, additional records were taken of the height and spread of the tree. Every effort was made to keep the trees free from disease, with the result that the trees were not materially disturbed by diseases or pests.

Silvered foliage made its appearance in one or two trees, but these all recovered their normal foliage and growth was not, apparently, affected. A fair amount of leaf curl (*Exoascus deformans*) was general over the whole plot in 1928. All the trees were sprayed with Lime Sulphur (1 in 30) in March, 1929, and since then no leaf curl has been noticed. Light attacks of leaf-curling aphis from year to year were controlled by spraying with a nicotine spray. In a field trial such as this, it was not to be expected that the trees would carry a crop of fruit ; but it was hoped that stock influence, if any, would be shown in such factors as length of new wood produced, girth of stem and spread of the branches.

Behaviour in the Field.

Wood Growth.

In regard to total wood growth made during the five years covered by the trial, there are not such great differences between these thirteen stocks as are shown, for example, in the apple stocks (3). Nevertheless, differences do exist. Hale's Early on Broad-leaved Shining Mussel (80 metres) made one-third more new wood than on Pershore (60 metres). Table IV gives the average total growth per tree during five years. It will be seen that they vary from Broad-leaved Shining Mussel down to Pershore in more or less even steps, yet there is a distinct gap between strong and weaker stocks, and most of them fall naturally into one of two groups. All the Mussels are in the more vigorous group while

the Damas stocks vary from the vigorous D, which made 79.3 metres' growth, down to the more dwarfing B, with only 62 metres of growth.

TABLE IV.

Hale's Early Peach. Average total growth of new wood during the five years 1925-29.

On Rootstock.	Number of trees.	Average per tree Metres.	S.E. of Mean.
B.L.S. Mussel ..	7	**79.8**	*3.5*
Damas D.	10	**78.6**	*3.4*
Brompton	8	**74.4**	*5.9*
N.L.S. Mussel ..	5	**73.8**	*5.8*
Damas C.	10	**71.9**	*2.7*
Common Mussel ..	8	**70.9**	*3.3*
Damas B.	6	**61.9**	*4.7*
Kroosjespruim ..	6	**59.7**	*2.8*
Pershore	8	**59.6**	*4.5*

Much the same difference has been found to take place in the selected St. Julien stocks.

Trials of peaches grown in pots were commenced in 1923, a second series being potted in 1924. The records of wood growth confirm, to some extent, the results obtained from the open ground trial with two exceptions : in pots Kroosjespruim gave much more vigorous trees and Common Mussel much weaker trees than in the open ground. The increased vigour of the trees on Kroosjespruim may have been due to the lack of fruit on these trees, but the reason for the decrease in the vigour of Common Mussel when grown in pots is not apparent. Results obtained from a stock trial with the trees grown in pots cannot be strictly compared with those from trees growing in the open ground. In pots the roots are necessarily restricted, as the pots are of equal size, and this may well have given the weaker root systems an advantage over the strong.

Height and Spread.

Table V shows the area covered by the trained trees in the field at the end of the fifth year.

This was calculated from three measurements of spread, taken at one-third, two-thirds and at the full height of the tree ; the mean of the spreads was then multiplied by the height of the tree.

TABLE V.

Hale's Early Peach. Average area per tree covered by trained trees after five seasons' growth.

On Rootstock.	Number of trees.	Mean per tree in sq. metres.
Brompton	8	4.92
B.L.S. Mussel	7	4.61
Damas D.	10	4.15
Common Mussel	8	4.11
Damas C.	10	4.02
Damas B.	6	3.94
N.L.S. Mussel	5	3.87
Kroosjespruim	6	3.66
Pershore	8	3.19

The area occupied by the trees falls into line with the grouping of the stocks by wood growth, except that, according to area occupied by the tree, those on Narrow-leaved Shining Mussel do not appear so vigorous as when wood growth only is considered.

Weight of the Trees.

In regard to weight of the trees when lifted, the records confirm the vigour grouping as indicated by wood growth. The greatest weight is shown by trees on the Mussel stocks and the least by those on Pershore and Kroosjespruim. There is no correlation between weight of tree at one year old and subsequent performance either in the open ground or in pots.

Girth of Stem.

It has been shown that the girth measurements of plum trees fall very well into line with those of new wood growth (4). The same is more or less true of peaches. Table VI shows the girth measurements of these trees. Owing to the comparatively low variation in this characteristic, it is possible to detect a definite gap between the vigorous and the less vigorous stocks; Damas B, which was not in either group for wood growth, can now, in consequence, be definitely relegated to the dwarfing group. Records were also taken of girth of the trees immediately below and at the union. Abnormal swelling at the union is quite unconnected with vigour or lack of vigour, at any rate in trees of this age.

TABLE VI.

Hale's Early Peach. Girth of stem of trained trees after five seasons' growth.

On Rootstock.	No. of Trees.	Mean in mm.	Standard Error.
N.L.S. Mussel ..	5	194	3.1
Damas D.	9	185	6.4
B.L.S. Mussel ..	6	184	9.1
Common Mussel ..	8	178	6.4
Brompton	7	178	7.1
Damas C.	9	174	4.6
Damas B.	6	159	4.2
Kroosjespruim ..	6	158	4.4
Pershore	6	150	9.1

Girth of rootstock below the union is also no indication of vigour, moreover there is no correlation between girth above and girth below the union within sets of trees worked upon the same variety of stock. Both in the field and in pots, trees worked upon Narrow-leaved Shining Mussel have shown abnormal swelling at the union.

Dead Wood.

Records of winter-killed wood removed from the trees in the spring following the severe winter of 1928-29 indicate that there is probably no variation in susceptibility to winter injury between the trees on the various stocks used in this trial other than that the larger trees have shown a tendency to throw more dead wood than the smaller.

FRUITING OF TREES IN POTS.

As previously mentioned, trials of peach trees in pots were commenced in 1923 and 1924. Records of fruiting were taken over the four years from 1925-28, dealing with weight and number of fruits, colour and time of ripening.

Seven varieties of stock were included in these trials in pots, namely the three Mussels, Brompton, Pershore, Damas C and Kroosjespruim. The trees were unpruned except for the removal of dead wood.

Throughout the trial there was no significant difference in the time of fruit ripening between the trees on the various stocks. Table VII gives the average weight of fruit borne by the trees over four years. The trees on Brompton have given considerably heavier yields than trees on the other stocks. The trees on

Kroosjespruim, in spite of the large amount of wood produced, have been unhealthy in the pot trials, and this probably accounts for the low weight of fruit.

TABLE VII.

Hale's Early Peach. Average total weight of fruit from trees under glass during four seasons.

Stock.	Unit.	Weight of Fruit (lbs.).
Brompton	7	24.6
Damas C.	8	21.9
N.L.S. Mussel	4	21.3
Pershore	4	19.7
Common Mussel	4	16.6
B.L.S. Mussel	4	16.4
Kroosjespruim	4	15.1

VALUE OF FRUIT.

For purposes of comparison the value of the fruit over the last three years of cropping, was determined by sorting the fruits into four colour grades and five weight grades at the time of picking. In the colour grading, fruits having less than one quarter of the surface coloured were given one point, one quarter to a half were given two points, a half to three quarters three points, and over three quarters coloured received four points. The weight grades were : under three, three to four, four to five, five to six and over six ounces. These grades were placed so that they formed two adjacent sides of a rectangle as in the diagram.

Colour.	under 3.	3-4.	ozs. 4-5.	5-6.	over 6.
1	2d.	3d.	6d.	9d.	1/-
2	2d.	5d.	8d.	1/-	1/4
3	3d.	7d.	10d.	1/3	1/8
4	3d.	9d.	1/-	1/6	2/-

It was considered that a peach weighing six ounces with full colour would be worth two shillings and that a fruit in the same size grade which was in grade three for colour would be worth one shilling and eightpence ; the remaining

squares were filled in with values as shown. It is not claimed that this represents the actual value of the fruits, it merely forms a means of estimating the value of fruits for purposes of comparison. Table VIII shows the value of fruits from each stock, calculated in this way. Hale's Early in pots has behaved considerably better on Brompton than on the other stocks. In point of value there is no real difference between the trees on Pershore, Damas C, Common Mussel and Broad-leaved Shining Mussel; Narrow-leaved Shining Mussel is above the average and Kroosjespruim below the average as regards value of the fruits.

TABLE VIII.

Hale's Early Peach. Average value per tree of three years' crop of trees under glass.

Stock.	No. of Trees.	£ s. d.
Brompton	7	3 5 .0
N.L.S. Mussel	4	2 17 0
Pershore	4	2 11 0
Damas C.	8	2 10 0
Common Mussel	4	2 3 0
B.L.S. Mussel	4	2 2 0
Kroosjespruim	4	1 18 0

CONCLUSION.

Too much value must not be placed on results from trials in pots, where the root run is restricted and the position of the pot in the glass house may exert an influence on the tree for better or worse. Even so, the pot trials have largely borne out the results obtained with trees planted in the open ground.

For general purposes Brompton and Common Mussel would probably be the most suitable stocks. Damas C has been consistently good in the trials at East Malling and should prove a valuable stock for peaches. Moreover, this stock is more readily propagated than Brompton or Common Mussel. Where space is limited Pershore or the St. Julien C mentioned in this paper would probably be more suitable than the more vigorous stocks. Methods of propagating the various stocks mentioned are described in a paper published from this Station in 1927 (5).

SUMMARY.

(1) Since 1921 three trials of Hale's Early Peach on a wide range of root-stocks have been carried out, two under glass in pots and a third in the field.

St. Julien A. Five years old.

St. Julien G. Five years old.

Hale's Early Peach on two selections of St. Julien showing contrasts in vigour.

Hale's Early Peach on the vigorous Brompton, five years old.

Hale's Early Peach on the less vigorous Pershore, five years old.

(2) In the nursery various incompatibilities have been met with, certain of the stocks in common use for plums and some seedlings of such varieties as Damas and Julien, proving totally incompatible with peaches. In other cases the incompatibility has been delayed, the trees dying subsequent to planting.

(3) While the restricted conditions to which the trees in pots were subjected have somewhat masked the effects of the rootstocks, clear differences in vigour have been shown by the trees in the field.

(4) Two distinct groups are apparent, the outstanding vigorous trees being those on Brompton and Common Mussel while Pershore and Kroosjespruim form a more dwarfing group of stocks. Clear differences in vigour are also apparent between trees on different seedlings of the same variety.

(5) Under glass the trees on Brompton have produced outstandingly the heaviest crops, while those on Kroosjespruim have consistently produced poor crops. There are no definite differences in cropping between trees on the other rootstocks tested.

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THE CROPPING OF RASPBERRY VARIETIES AT EAST MALLING.

By N. H. GRUBB.

A BRIEF report* summarizing the data on the cropping of raspberry varieties collected during the seven seasons 1919 to 1925, was published in 1926. The plants from which these data were obtained were chiefly in single rows or parts of rows ; in only a few cases were the varieties planted in more than one place, the exceptions being mainly those varieties of which stocks had been obtained from more than one source. The majority of the varieties were exactly as they had been planted when received from the senders, with the exception that any mixtures of varieties had been separated.

Early in 1926 a further trial was planted. In this case all the canes were obtained from stocks already growing at the Research Station, and known to be free from mixtures or " rogues." This trial was arranged in six blocks. Four blocks each contained one row 56 feet long of each of the more promising varieties ; the other two blocks each contained one similar row of several less promising varieties and of a few promising sorts of which enough canes for four rows were not then available.

The ground used for this trial was believed to be fairly uniform, and had been uniformly manured and cropped for at least six years, probably longer. It was considered to be in " good heart," at the time of planting. The site has the disadvantage of being somewhat exposed to winds ; this fact has probably reduced the weight of fruit obtained. Allowing for this, we can consider the yields reasonably satisfactory.

In January, 1924, half the ground was subsoil-ploughed by means of a tractor-drawn plough, the remainder being single ploughed. Shortly before the raspberries were planted, in January, 1926, the whole area was subsoil-ploughed by means of a horse-drawn plough. The tractor-drawn plough undoubtedly went some inches deeper than the horse-drawn plough, and this may have influenced the behaviour of the raspberries on the part so treated. Of the four 56 foot rows of the more important varieties two in every case come on the deeply subsoiled part and two on the other part. Thus the deeper subsoiling of this part cannot have altered the result. Although the raspberries on the deeply subsoiled part have on the average cropped more heavily than on the

* " Raspberry Varieties and their Cropping." *Journ. of Pom. & Hort. Science*, Vol. V, No. 2. March, 1926.

other part, it is impossible to say whether this is due to the subsoiling or to some other factor, such as soil fertility.

The canes used for planting were as healthy as any then available. Nevertheless, diseases have seriously injured certain varieties, and only a small minority have remained practically healthy throughout the trial. A repetition of the trial with material completely free from disease (where obtainable) is now being planned, and will almost certainly give somewhat different results. It is unfortunately impossible to estimate how far the disease factor has affected cropping ; the matter is discussed in some detail below, and the varieties most affected by diseases are indicated. It can be said with confidence, nevertheless, that few, if any, of the varieties in the trial are even now more diseased than average commercial stocks, and the majority are certainly more healthy.

Arrangement of Trial.

The arrangement of the six blocks is shown on p. 34. All varieties were spaced in the same way, each row consisting of twenty-eight plants 2 feet apart. The rows were 12 feet apart, and the end of one variety was 12 feet from the beginning of the next in the same row. The spaces between the rows, and between varieties in the row, were planted in the winter of 1927-28 with black currant bushes 5 feet apart.

Although several varieties have made very vigorous growth, the canes in favourable seasons running to 6 or 7 feet in height, there has been very little trouble from the spreading of " spawn " from row to row. Beyond a periodic " roguing," it has not been found necessary to take any steps to prevent such spreading.

Cultural Treatment.

The cultural treatment has been similar to that given to raspberries by many commercial growers. In the late winter each year the canes have been thinned to four or five per stool ; those left have been tipped, lightly except with the tallest growing varieties, and tied to wires at a height varying with the variety, but never more than 4 feet. The old fruiting canes have been cut out at varying times in the autumn.

The spaces between the raspberries and black currants have been ploughed each winter, the ploughing being as shallow as would allow of covering weeds and any manure given. The summer cultivations have been frequent and shallow ; the rows have been regularly hoed, and until 1929 the stools were kept separate as far as possible by hoeing out the " spawn."

Manuring.

In the winter of 1925-26, immediately before the raspberries were planted, the land received 20 tons of London dung and $6\frac{1}{4}$ cwts. of rape dust per acre.

The dung was repeated in March, 1927, and again in February, 1929. In February, 1928, it received one ton per acre of high grade shoddy.

In 1926 generous dressings of artificials were given, mainly because the raspberries were then interplanted with cauliflowers. These included, per acre, 2 cwts. of sulphate of ammonia, 4 cwts. of superphosphate, and 2 cwts. of sulphate of potash in April, with 14 cwts. of fish meal and 1½ cwts. sulphate of ammonia in August.

Plan of Trial. Planted February, 1926.

	A.	B.	C.	D.
Block 6.	Baumforth A. North Ward. Black Antwerp A. (*Perthshire C.*) Profusion. Hornet A. (*Cambridgeshire.*)	Baumforth B. Helston. Black Antwerp A. (*Perthshire B.*) Red Cross. Hornet A. (*Kent B.*)	Reader's Perfection. Devon. Black Antwerp A. (*Perthshire A.*) Lloyd George. Hornet A. (*Perthshire A.*)	Red Antwerp C. Bountiful A. Royal. Bountiful B. Hornet A. (*Kent B.*)
Block 5.	Hornet A. Winkler's Seedling. Inkpen Wonder. Laxton's Reward A. Red Antwerp A. Brighton.	Hornet C. MacLaren's Prolific. Red Magnum. L75. Mitchell's Seedling. Latham.	Hornet D. Goliath. Paradise Berry. L79. Prior's Prolific.	Hornet E. Semper Fidelis A. Seldon Seedling. L81. Norwich Wonder.
Block 4.	Reader's Perfection. Devon. Black Antwerp A. (*Perthshire A.*) Lloyd George.	Red Antwerp C. Bountiful A. Royal. Bountiful B.	Baumforth A. North Ward. Black Antwerp A. (*Perthshire C.*) Profusion. Hornet A. (*Cambridgeshire.*)	Baumforth B. Helston. Black Antwerp A. (*Perthshire B.*) Red Cross. Hornet A. (*Kent B.*)
Block 3.	Hornet A. (*Perthshire A.*) Hornet A. (*Kent B.*) Red Cross. Black Antwerp A. (*Perthshire B.*) Helston. Baumforth B.	Hornet A. (*Kent A1.*) Hornet A. (*Cambridgeshire.*) Profusion. Black Antwerp A. (*Perthshire C.*) North Ward. Baumforth A.	Hornet A. (*Kent A1.*) Bountiful B. Royal. Bountiful A. Red Antwerp C.	Hornet A. (*Perthshire A.*) Lloyd George. Black Antwerp A. (*Perthshire A.*) Devon. Reader's Perfection.
Block 2.	Norwich Wonder. L81. Seldon Seedling. Semper Fidelis A. Hornet E.	Prior's Prolific. L79. Paradise Berry. Goliath. Hornet D.	Latham. Mitchell's Seedling. L75. Red Magnum. MacLaren's Prolific. Hornet C.	Brighton. Red Antwerp A. Laxton's Reward A. Inkpen Wonder. Winkler's Seedling. Hornet A.
Block 1.	Hornet A. (*Kent A1.*) Bountiful B. Royal. Bountiful A. Red Antwerp C.	Hornet A. (*Perthshire A.*) Lloyd George. Black Antwerp A. (*Perthshire A.*) Devon. Reader's Perfection.	Hornet A. (*Kent B.*) Red Cross. Black Antwerp A. (*Perthshire B.*) Helston. Baumforth B.	Hornet A. (*Cambridgeshire.*) Profusion. Black Antwerp A. (*Perthshire C.*) North Ward. Baumforth A.

Two Bays, B and C, subsoiled by tractor drawn plough, January, 1924.

Remainder single ploughed.

Whole area subsoiled by horse-drawn plough, January, 1926.

In April, 1927, a dressing of 21 cwts. per acre of ground lime was given—as it was thought at that time that lime might reduce the injury to the raspberries from " blue stripe wilt." This was followed in May by 5 cwts. per acre of Peruvian guano. In May, 1928, following the planting of black currants, one ton per acre of meat and bone was given. In 1930 the only manurial treatment of any sort was 8 cwts. per acre of meat and bone, given in February.

It will thus be seen that the raspberries have by no means been starved. The manuring has been largely nitrogenous, but the dressings of superphosphate, meat and bone, and sulphate of potash would help to preserve the balance.

Comparative Yields.

Table I gives the average yield of fruit in cwts. per acre of each variety of which four replicates were planted. The varieties are placed in order of their average crop for the whole four years; this appears in the right hand column. The other columns show the average crop (of the four replicates) for each year separately, and, in block type, the position of each variety in each year. We can thus see at a glance to what extent varieties have relatively improved or fallen off in their cropping from year to year. It is not considered worth while to give in tabular form the yield of those varieties of which only two replicates were planted ; a few of these are mentioned below.

It must be remembered that although yield of fruit is necessarily an important measure of the value of a variety, it is not the only such measure. Amongst raspberries, as amongst other fruits, the quality of the fruit is of almost equal importance. A variety which yields a very heavy crop may be almost worthless on account of the poor quality of the fruit : two such varieties are mentioned below, i.e. Latham and Helston ; whilst a variety not in the front rank in cropping may be of considerable value on account of the size, colour, time of ripening, or other characteristics of its fruit, e.g. Royal. An attempt is made to cover some of this ground in a later section, " Notes on Varieties."

It should be observed that the four-year averages given in Table I include the crop of 1927, the first year of cropping in this trial. As will be seen, Lloyd George was the only variety which in that year exceeded 10 cwts. per acre, and most were far below this figure. If the average is taken for the three years, 1928-30 only, all the figures are of course higher, and they more nearly represent what the varieties can be expected to do in our soil. The order of cropping remains the same, with the exception that Red Antwerp C comes above Lloyd George.

The Statistical Aspect.

From the statistical point of view, these results are more satisfactory than might have been expected. Since the blocks (see Plan, p. 34) are not strictly

Table I.

Cropping of Raspberry Varieties, in Cwts. per acre.

Variety.	Source.	1927. Crop.	1927. Pos.	1928. Crop.	1928. Pos.	1929. Crop.	1929. Pos.	1930. Crop.	1930. Pos.	4 year Average.	Per Cent.
1. Baumforth A. ..	Kent A. ..	7·3	= 3	43·7	1	50·5	1	58·0	3	39·9	166
2. Helston ..		6·8	= 5	41·0	2	45·9	2	53·4	7	36·8	153
3. Lloyd George ..		11·4	1	32·6	5	40·3	4	62·0	1	36·6	152
4. Red Antwerp C. ..		6·8	= 5	37·9	3	40·4	3	58·8	4	36·0	150
5. North Ward ..		4·6	10	33·8	4	34·0	6	57·1	5	32·4	137
6. Red Cross ..		8·5	2	26·5	7	31·3	8	60·1	2	31·6	132
7. Royal ..		7·3	= 3	31·8	6	33·1	7	50·1	8	30·6	127
8. Bountiful A. ..		6·1	= 7	23·0	9	35·3	5	56·0	6	30·1	125
9. Baumforth B. ..	Perthshire A. ..	6·1	7	25·8	8	30·7	9	41·2	10	25·9	108
10. Hornet A. ..	Kent A1 ..	3·4	=13	12·4	16	22·0	11	41·4	9	19·8	82
11. Hornet A. ..	Perthshire A. ..	3·1	17	12·6	15	20·3	13	39·8	11	18·9	79
12. Bountiful B. ..		4·9	9	14·2	=11	16·7	18	39·3	12	18·8	78
13. Hornet A. ..	Kent B. ..	3·8	=11	13·0	13	20·6	12	35·1	13	18·1	75
14. Black Antwerp A. ..	Perthshire A. ..	3·4	13	12·7	14	24·9	10	28·3	16	17·3	72
15. Reader's Perfection ..		1·4	20	14·2	11	17·5	17	33·3	14	16·6	69
16. Black Antwerp A. ..	Perthshire C. ..	2·7	=18	12·1	17	20·2	14	29·9	15	16·2	68
17. Profusion ..		3·8	=11	11·4	18	17·6	16	26·3	18	14·8	62
18. Devon ..		3·4	=13	16·3	10	18·6	15	20·4	20	14·7	61
19. Hornet A. ..	Cambridgeshire	3·4	=13	8·7	19	16·6	19	26·7	17	13·8	55
20. Black Antwerp A. ..	Perthshire B. ..	2·7	=18	7·9	20	14·3	20	22·8	19	11·9	50

randomized, it is not possible to calculate exactly the error due to position. The standard error for the whole experiment, calculated as if the blocks were randomized, indicates that differences of 22 per cent. of the general mean for all varieties between any pair of averages are significant ; but since the more or less formal arrangement of the blocks may have slightly reduced the real errors, it will be safer to increase this margin, and to regard as significant only those differences which amount to, say, 30 per cent. The last column of Table I shows the four-year averages calculated as percentages of the general mean for all varieties ; from these figures it is easy to see which differences amount to 30 per cent.

If we may take it, then, that differences of this magnitude are significant, we find the varieties grouped as shown by the brackets in the last column of Table I. Between Baumforth B and the first stock of Hornet A, where a space has been left in the table, there is a definite gap. It is fairly safe to consider that all the varieties above this gap have cropped significantly more heavily than any of the varieties below it. Incidentally, we find that, in the crops of the separate years, only twice has the highest variety below the gap come above the lowest variety above the gap.

Apart from this, the brackets show that, whilst there is no significant difference in cropping between the first five varieties in the table, Baumforth A has cropped significantly more heavily than all varieties below North Ward ; that the first four varieties have cropped significantly more heavily than all below Bountiful A, and so forth.

These larger differences then, are probably significant, i.e., they would probably be repeated if the trial were repeated under similar conditions. How far they may be due to diseases is discussed below ; but it is at least interesting to note that the leading variety, Baumforth A, has consistently been the healthiest in the whole trial.

Other Varieties.

The remaining varieties, of which only two 56 foot rows were planted, also show very large differences in cropping. One variety, the American " Latham," actually comes above Baumforth A in average crop for the four years, at 43 cwts. per acre. But this variety, as will be seen below, is so poor in fruit quality, at least as grown at East Malling, as to be negligible. " Laxton's Reward," with an average crop of 36.2 cwts. per acre, comes between Lloyd George and Red Antwerp C ; and the continental variety, " Winkler's Seedling," comes just above North Ward, and would have come higher still, but for a surprisingly light crop in 1930. Two other varieties which may in certain cases be worth growing on account of their fruit quality, are " MacLaren's Prolific," with 27.4 cwts. per acre, and " Hornet E," with 27 cwts. The former

is a good dessert variety, and the latter is the latest ripening of all known varieties. On the other hand, two varieties, "Semper Fidelis A" and "Mitchell's Seedling," both come below the last variety in Table I. Both these varieties, as also "Devon," have made very gappy rows, owing to the death of many plants. Probably much better stocks of them could be obtained. It must be repeated, however, that the standard error of the crops of all these secondary varieties is large, and only the extreme differences could safely be regarded as significant.

Since the present trial was planted, early in 1926, a number of promising or noteworthy varieties have been received from various sources. It has not yet been possible to arrange for a further trial to include these varieties, but records of their crops have been made each year since they began to crop. Whilst a few of these varieties are mentioned below, it should be understood that these figures must be taken with much caution; on further trial the results may in some cases prove to be widely different from those here given.

Two of the most interesting—and disappointing—are American varieties. "Cuthbert," one of the most widely grown varieties in America, planted in winter 1926-27, has yielded two negligible crops in 1928 and 1929, the quantity of fruit being equivalent each year to less than 3 cwts. per acre. "June," a new extra early American sort, planted in winter 1927-28, yielded 3 cwts. per acre in 1929 and $7\frac{1}{2}$ cwts. per acre in 1930. Unless it can be induced to crop more heavily, even its extreme earliness will not make it worth planting.

"Burnett Holm Seedling," a Scottish variety, planted in winter 1926-27, made poor growth in 1927 and its crop was not recorded until 1929. In that year it produced $11\frac{1}{2}$ cwts. per acre, and in 1930, $23\frac{1}{2}$ cwts.

Three varieties planted in winter 1928-29 cropped for the first time in 1930. By far the most promising is the German variety "Preussen," which yielded about $9\frac{1}{2}$ cwts. per acre. This, in the first year of cropping, is exceptionally heavy for a variety which does not make large numbers of canes soon after planting.

To the question, "which of these varieties are really worth growing commercially?" no definite answer can be given. In the first place, although our larger differences in cropping are undoubtedly significant, a trial on a different soil would probably give clear-cut differences in the order of cropping. We are fairly sure that certain varieties like Baumforth A, Lloyd George and Red Cross will crop more heavily than the general run of varieties almost wherever they are grown; but there are probably other varieties which have distinct soil preferences.* Then again, there is the question of fruit quality, already referred

* Readers may be interested to compare the results here given with those of similar trials at the Long Ashton Research Station, reported by Swarbrick in the Annual Report of that Station for 1930.

to. For our conditions a variety like Royal (seventh in the table) is probably worth more (provided it will produce enough cane) than Helston (second in the table), on account of the much greater size of its fruit. (The difference in cropping between Helston and Royal is not significant, but even if it were, the point would still hold.) It would be of no use for a grower, who was restricted to a local market for dessert fruit, to plant a variety like Baumforth A, however heavily it might crop, since Baumforth A could never be a dessert variety.

On the whole, it might perhaps be said that varieties which come below the gap in the table would have to have some very exceptional quality to make them worth planting in our soil. Such varieties may exist. Bath's Perfection, for instance (not included in the current trial), would almost certainly come in the lower half of our table ; yet its extreme earliness, and the very bright colour of its fruit, might make it sometimes worth planting.

Stocks from Different Sources.

In the previous report, already referred to, figures were given to show the cropping of several stocks of the same variety from different sources. In the present trial are included four of these stocks of Hornet A and three of Black Antwerp A. The sources of these stocks are given in Table I, so that the results may be compared with those given in the previous report.

In both reports we find that the stocks of Hornet A from the farms described as " Kent A1 " and " Perthshire A " have cropped more heavily than the other two, though the differences are probably not significant. The relative position of the two former has been reversed since the earlier report, and there is some variation from year to year ; but the difference between the two is now small. In both trials we also find that the stock of Black Antwerp A from the farm " Perthshire A " has cropped more heavily than the other two. As these differences have been more or less repeated, it seems possible that they are the result of something other than mere chance. Observations have shown that the heavier cropping stocks of these varieties have nearly always made the better growth ; their heavier crop is probably a reflection of the larger amount of cane they have made. The available data do not suggest that the better cropping of stocks have been less affected by disease than the others.

It is certainly not impossible, even where the disease factor is excluded, that different stocks of the same variety may grow and crop differently. Growers would do well, not only to try to secure canes for planting from healthy stocks, but also to make sure that the stocks are vigorous, apart from disease. It is not advisable to take canes for planting even from apparently healthy stocks which have made weak plants and gappy rows. Some allowance must of course be made for varietal habit, as, for instance, in Royal, which seldom makes a dense row.

Diseases.

Table II gives a rough estimate of the effect certain diseases have had on the cropping of the varieties mentioned in this report. The position is not as satisfactory as one could wish, particularly where "mosaic" is concerned. Several varieties are entered in the Table as showing symptoms of mosaic in "all" plants. In these cases we have never been able to find a plant, either in our own stocks or elsewhere, which we could be reasonably sure was free from mosaic. We have thus no means of judging how the variety would grow and crop if it were entirely free from the disease. Of these varieties, the most important are Red Cross and Royal. Although it is occasionally possible to find canes of these varieties which appear to show no symptoms of mosaic, we have found that such canes, when propagated, invariably produce plants showing at least slight symptoms.

In all such cases, however, it will be extremely difficult to get more satisfactory results than those here discussed, unless and until it becomes possible to obtain stocks definitely free from mosaic. The stocks now in common commercial use are certainly not more free from mosaic than our own; our results are thus at least some indication of the value of average commercial stocks of these varieties in such a soil as ours.

The notes in Table II on the more recently acquired varieties, Burnett Holm Seedling, Cuthbert, June and Preussen, must be taken with caution. Our experience is as yet too slight to show how far these varieties are susceptible to the diseases concerned; we can only show how far they have actually been affected up to the present. We have some reason to fear that Preussen may be susceptible to considerable injury by mosaic, although only two or three of our plants have as yet shown any symptoms.

Blue Stripe Wilt is probably the least serious, commercially, of the three diseases mentioned. It is rare to find it causing any notable reduction of crop, and although in certain seasons a few varieties in our plantations have lost a considerable proportion of their canes before the fruit was ripe, it is doubtful if we have ever had a reduction approaching 50 per cent. in the crop, even in the worst cases. Recent research indicates that the severity of the attack of the disease is more dependant on local soil and seasonal conditions than on the initial infection of the stock with the causal fungus; and the problem of control is therefore of a local nature and exceedingly complex. For these reasons the question of the infection of a variety with the disease may be largely ignored in securing canes for fresh plantations.

The cases of Devon and Red Cross and of Mitchell's Seedling and Semper Fidelis A (not given in Table II) are obscure. It seems very unlikely that the death of many canes or stools of these varieties was entirely due to Blue Stripe Wilt; more probably the cause was a combination of diseases and seasonal factors.

TABLE II.

Estimated Injury by Disease.

	Mosaic. Proportion of Plants.					
	Showing Symptoms.	Severely Injured.	Slightly Injured.	Cane-Spot Injury.	Blue Stripe Wilt Injury.	Remarks.
Baumforth A. ..	A few	None	Very few	Negligible	Slight	Healthiest in trial.
Baumforth B. ..	Many	Very few	Many ?	Moderate to severe	Slight	Reasonably healthy.
Black Antwerp A. ..	All	Few	Great majority	Negligible	Very slight	Vigour reduced by mosaic ?
Bountiful A. ..	All	Few	All ?	Slight	Very slight	Reasonably healthy.
Bountiful B. ..	All	Several	All ?	Very slight	Very slight	Vigour reduced by mosaic ?
Burnett Holm Seedling	All	Few	All ?	Negligible	Slight	Reasonably healthy.
Cuthbert ..	Majority	None	Few ?	Very slight	Moderate	Healthy.
Devon ..	Great majority	Several	Great majority	Moderate	Slight	Many stools died, cause unknown.
Helston ..	A few	Very few	Few	Very slight	Slight to moderate	Reasonably healthy.
Hornet A. ..	All	Few	Majority ?	Very slight	Very slight	Vigour reduced by mosaic ?
Hornet E. ..	All	Very few	All ?	Slight	Very slight	Reasonably healthy.
June ..	All ?	None	Very few ?	Negligible	Moderate to severe	Fairly healthy.
Latham ..	All	None	Very few ? or all ?	Very slight	Slight	Fruit quality spoilt by mosaic ?
Laxton's Reward A. ..	A few	Very few	Few	Slight	Slight to moderate	Reasonably healthy.
Lloyd George ..	Several	Few	Several	Negligible	Slight	Reasonably healthy.
MacLaren's Prolific ..	Very few	None	None ?	Negligible	Slight	Healthy.
North Ward ..	Few	None	Very few	Negligible	Very slight	Healthiest except Baumforth A.
Preussen* ..	Few	Very few	Few	Very slight	Moderate	Healthy except for Blue Stripe Wilt.
Profusion ..	All	Several	Majority ?	Very slight	Slight	Vigour reduced by mosaic ?
Reader's Perfection ..	All ?	Several	Majority	Moderate	Moderate	Seems to have become healthier since 1927.
Red Antwerp C. ..	Majority	Few	Few	Slight or moderate	Slight	Crop slightly reduced by mosaic ?
Red Cross ..	All	None	None ? or all ?	Very slight	Negligible	Many canes died 1927 and 1928, cause unknown.
Royal ..	All	None	All ?	Negligible	Slight	Reasonably healthy.
Winkler's Seedling ..	All	Few	All ?	Very slight	Slight	Vigour reduced in 1929 and 1930, perhaps by mosaic ?

* We have had Preussen for only two years and cannot yet properly judge its susceptibility to diseases.

The notes in this table are based partly on the present writer's observations and partly on hitherto unpublished data collected by Mr. R. V. Harris

NOTES ON VARIETIES.

The following notes cover points which cannot very well be presented in tabular form. Fruit quality is often as important as yield, and even the habit of growth must be considered. A more detailed description of the majority of the varieties may be found in an earlier report.*

Baumforth A.—Fruit midseason, ripening over long period, medium to large, round, soft, fairly good colour, very acid, suitable only for cooking and jam, much liked by jam-makers. Growth usually very vigorous, sometimes medium on heavy soils. Succeeds on great variety of soils. Appears to be very drought resistant. Usually very healthy, rarely much weakened by mosaic.

Baumforth B.—Fruit midseason, medium to large, conical, usually very firm, characteristic dull purplish colour, very sweet, pleasant flavour, chiefly a dessert fruit, not liked by jam-makers. Rarely large enough for punnetting. Growth usually vigorous when healthy. Succeeds on most soils if kept healthy. Considerably injured by mosaic. Often requires spraying for cane spot.

Black Antwerp A.—A Scottish variety rarely worth planting in the south of England, growth too weak, even when healthy. Sometimes dwarfed by mosaic.

Bountiful A.—Fruit midseason, medium to large, roundish conical, often rather soft, fairly good colour, acid or subacid. Growth usually vigorous or very vigorous. No plants yet found quite free from mosaic, rarely seriously injured by it. Slightly susceptible to cane spot.

Bountiful B.—Fruit midseason, medium to large, conical, moderately firm, rather dark colour, sweet or subacid. Growth rather weak, often reduced by mosaic ; no plants yet found free from mosaic. Might be better if healthy stock could be obtained.

Burnett Holm Seedling.—Fruit late midseason, medium to large, nearly round, moderately firm, good colour, not turning dark when over-ripe, sweet. Well grown fruit is sometimes large enough for punnetting. Growth fairly vigorous, spreading. Seems to require shelter from wind for best results. No plants yet found free from mosaic, rarely seriously injured by it.

Cuthbert.—One of the leading American varieties. Fruit too small and crop too light so far to be of any value. In our soil this variety makes more " spawn " than Lloyd George.

Devon.—Fruit late, large when well grown, conical, moderately firm, fairly good colour. Growth usually vigorous, best in heavy soil, if well drained. Our stock has nearly died out from some unknown cause. Difficult to find

* " Commercial Raspberries and their Classification." *Journ. of Pom. and Hort. Sci.* 1922, **3.** 11-35.

plants free from mosaic, sometimes considerably injured by it. Often suffers from a form of " chlorosis " which is not understood, and may be a disease.

Helston.—Fruit late midseason, hardly above medium size, roundish conical. Moderately firm, dull colour, rather acid. Growth vigorous, rarely reduced by mosaic. Even the heavy cropping of this variety hardly makes it worth planting here ; the fruit is too small and poorly coloured.

Hornet A.—Probably the best known of the numerous " Hornets." Rarely crops well enough nowadays to be worth planting. Fruit early midseason, generally large, round, somewhat soft, sweet, fine flavour, very attractive when well grown. No plants yet found free from mosaic, sometimes considerably injured by it.

Hornet E.—Fruit very late, medium to large, conical or roundish, fairly firm, fairly good colour, sweet. Usually vigorous, makes rather few canes. No plant yet found free from mosaic ; rarely much injured by it.

June.—An American variety valued for its extreme earliness. Here the fruit, although bright coloured, is too small and " crumbly," and the crop is at present too light, to be of any value. Crop probably reduced by Blue Stripe Wilt.

Latham.—This also has a great reputation in America, chiefly for its heavy and regular cropping. Although growth here is very vigorous, every plant shows symptoms of mosaic. The immense crop consists of small " crumbly " fruit, and is of very little value ; a healthy stock might prove much better.

Laxton's Reward A.—Fruit midseason, medium to large, roundish conical, rather soft, good colour, not turning dark, sweet, good flavour. Growth vigorous, nearly erect. Generally healthy. Whilst this variety is promising here, we have not yet seen it cropping elsewhere, and do not know if it has soil preferences.

Lloyd George.—Fruit midseason, very large on young plants, medium to large on older plants, long conical when well grown, sometimes rather soft, fairly good colour, turning rather dark, variable in flavour, generally sweet. Old plants bear only a small proportion of fruit large enough for punnetting. Makes very many canes, vigorous, succeeds on most soils. Rather readily infected with mosaic, and apt to be considerably dwarfed by it ; severely affected plants often crop poorly. Susceptible in damp soils, under certain seasonal conditions, to a rotting of the roots and underground stems which may result in the death of a large proportion of the canes in the spring. In spite of its faults, this is probably the best general purpose variety at present available.

MacLaren's Prolific.—Fruit early midseason, medium to large, conical or roundish, fairly firm, fairly good colour, sweet, good flavour. Growth vigorous, nearly erect. Few plants slightly infected with mosaic, generally very healthy.

North Ward.—Fruit late midseason, large to very large, conical, fairly firm, good colour, sweet or subacid, pleasant flavour, large enough for punnetting when well grown. Growth vigorous, not very erect. Appears here to be rather subject to drought injury. Usually very healthy. The very few plants so far found with mosaic may have been somewhat dwarfed by it. We have not yet seen this variety cropping elsewhere, and do not know its soil preferences.

Preussen.—Fruit midseason, large to very large, roundish or short conical, fairly firm here, said to be soft in some places, very bright colour, very sweet, fine flavour. Very vigorous, erect, canes rather few. This is the most promising of our recent acquisitions, and should be of great value if it can be kept healthy. One or two of our plants appear to be slightly dwarfed by mosaic. Blue Stripe Wilt has killed several canes.

Profusion.—This variety appears to have lost its value, perhaps partly owing to mosaic, from which it is apparently never free. We do not know of any district where it is now being planted.

Reader's Perfection.—Fruit late midseason, medium to large, short conical, fairly firm, dull colour, rather acid. Growth very vigorous when healthy, much dwarfed by mosaic; difficult to find plants free from mosaic. Sometimes requires spraying for cane spot. Seems to be less injured by mosaic now than some years ago. Very susceptible to, and sometimes injured by, Spur-blight. Sometimes severely injured by Cane blight.*

Red Antwerp C.—Fruit midseason, medium size or a little more, roundish, fairly firm, good colour, acid. Growth vigorous, erect. Considerably dwarfed by mosaic. On account of its heavy cropping, this old variety may still be worth planting if a healthy stock of it can be obtained.

Red Cross.—Fruit midseason, medium to large, sometimes very large, conical, sometimes rather soft, rather dull colour, sweet, pleasant flavour. In good seasons much of the fruit is large enough for punnetting. Growth usually very vigorous, spreading. Appears to succeed in most soils. No plant yet found free from mosaic, but vigour is apparently not reduced by it, even when leaf symptoms are very striking. Should not be planted near mosaic-free stocks of varieties susceptible to mosaic injury. Many canes died and plants became weak in 1927 and 1928, cause unknown; crops of 1928 and 1929 considerably reduced; recovery was not complete till 1930. Now more vigorous than ever before.

Royal.—Fruit midseason, large to very large, short conical, generally firm, fairly good colour, turning dark, here rather acid, sometimes sweet. One of the best varieties for punnetting. Growth vigorous, erect, canes usually very few.

* Notes on Spur-blight and Cane blight are based on hitherto unpublished data collected by Mr. R. V. Harris.

No plant yet found quite free from mosaic, probably seldom dwarfed by it. The canes are often too few to allow this variety to crop well; but the large fruit sometimes makes it worth planting even where the crop is not heavy.

Winkler's Seedling.—Fruit midseason, barely medium size, roundish, firm, bright colour, sweet. Growth vigorous, erect. No plant yet found free from mosaic; sometimes considerably dwarfed by it. The fruit of this continental variety is here too small; where it is larger, the variety is useful for its heavy cropping and bright coloured fruit.

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The writer would like to express his grateful thanks to many members of the staff at East Malling Research Station whose work has made this report possible. At one time or another, many members of the Recording Staff have helped in recording the weight of fruit; but the chief burden has fallen on Mr. A. C. Painter.

The statistical examination of the results was kindly undertaken by Mr. T. N. Hoblyn, whose advice on the manner of presenting them has also been extremely helpful. The notes on diseases, and particularly Table II, have been prepared in collaboration with Mr. R. V. Harris, who has very kindly allowed the use of many hitherto unpublished notes.

Summary.

The fruit yield of fifteen varieties of raspberry, for the period of 1927-30, is reported and examined statistically. Differences in average yield of 30 per cent. of the general mean for all varieties are, in this trial, probably significant. The yield of several other varieties, and of two varieties from various sources, is also given.

Fruit quality must be considered, as well as yield. The heaviest yielding variety in this trial, Baumforth A, is suitable only for cooking and jam. The second, Helston, often produces fruit too small and poorly coloured to be profitable. The seventh, Royal, on account of its large fruit, is often worth more than varieties of heavier yield.

The extent to which certain diseases have injured varieties in the trial is estimated. Completely healthy stocks of certain varieties (if obtainable) might have given relatively heavier yields.

Notes on individual varieties indicate the suitability of each for certain purposes, their soil preferences (where known), and other points of interest.

SOME "ROGUE" VARIETIES OF BLACK CURRANTS.

By J. AMOS.

The importance of variety in the case of bush fruit was fully stressed in the work dealing with the classification of Black Currants published by this Station in 1920 (1). It was there shown that apart from distinct botanical characters, which enabled the varieties to be arranged into groups, there were in addition wide differences in cropping between many of the varieties. This emphasized the fact that variety was the " key " to the whole economic position.

Whilst it is probably true that the majority of varieties planted in recent years have been true to name and of some commercial value, there are nevertheless certain rogue varieties in circulation which are worthless for they either set no fruit at all or at the best yield a very small crop. These rogue varieties have been found to be widely distributed during the past few years and have been substituted for Baldwin Black—a heavy cropping variety that has of late been widely planted. These worthless varieties have been received both from nurserymen and from growers' plantations. Frequently it has been possible to trace, from grower to grower, the same variety which has been passed on as cuttings or bushes. In practice the cuttings are propagated from the newly planted bushes either for home use or for distribution and in this way a variety is quickly increased. It may be asked why a worthless strain comes to be propagated. There are probably two reasons (1) failure to recognize the variety and (2) attributing the failure to set a crop to adverse conditions rather than to an inherent cause. This non-setting of the fruit in successive years finally ends in grubbing the bushes after much time and money have been lost. In the meantime the stock from such bushes may have been distributed, in quite good faith, with the same disastrous results in the end.

In order to ascertain whether these rogue varieties comprise one or more types, collections have been obtained from various sources during the past few years for the purpose of comparing the different types and for studying their botanical characters, with a view to finding a means for their future identification. One point of interest is the purity of the stocks of these rogue varieties. In no case was it found that two rogue varieties were mixed. In the three cases in which mixtures did occur, the admixtures were the well known standard varieties, French, Boskoop and Goliath respectively.

In all, some twenty collections have been examined and it has been found that these consist of only three distinct botanical types. The origin of these types is uncertain but there is good reason to believe that they came orginally from the Continent.

So far as our experience goes these types have been substituted only for the variety Baldwin, hence the reason for comparing them with this variety. They have been grown in rows adjacent to Baldwins so that a detailed study could be made of their botanical characters and cropping capabilities when grown under identical conditions.

This paper gives detailed descriptions of the types isolated, together with that of Baldwin, as an aid to their identification.

Owing to the lack of knowledge as to the origin of these rogue types they will for convenience be referred to as A, B and C. Whilst these types bear some superficial resemblance to the true Baldwin the differences between them, when a detailed comparison is made, are seen to be very distinct.

The table* gives their descriptions, and the outstanding differences when compared with Baldwin are given in italics. Winter and summer descriptions are separated so as to aid identification during either season.

General Characters.

True Baldwin.

The bushes of this variety are much weaker in growth than the rogue varieties. The buds are longer, more conical and the bud scales much more loosely arranged ; they are also more protruding. The racemes are of medium length and on the whole shorter than those of the rogue types. The flowers are also less coloured. The stigmas are generally on a level with the anthers and in this respect differ widely from the rogue types in which the styles are very long so that the stigmas are well above the anthers. The leaves are regular in shape ; the central lobe is long and acute, the lateral lobes short but acute. The leaf sinus is deep. The lamina is dark green in colour. The fruit is of medium size and almost invariably sets well. It is the earliest to come into leaf and flower but the fruit hangs late.

Rogue Type A. (*Received from ten sources.*)

The bushes are very vigorous, large, compact and much branched. The buds are oval and greenish, the bud scales very compact and less protruding than in the Baldwin. The racemes are medium in length to long, waved, horizontal. The flowers are pinkish in colour. The styles are long and the stigmas much above the anthers. The leaves are regular, the central lobe short, pointed and very broad. The lateral lobes are very short, obtuse and often rounded. The lamina is often cupped. The leaf sinus is deep and the lobes often overlap. The lamina is dull green, often with yellow mottling. The fruit is small and acid, the skin hard and tough. It is a midseason variety and very few flowers set.

* Pages 50 and 51.

Rogue Type B. (*Received from eight sources.*)

The bushes are very vigorous, compact, and much branched. The wood is much stouter than either Baldwin or Type A and is darker in colour. The buds are brownish red, very round and plump, the scales chaffy and loose, and protrude but slightly. The racemes are long, rigid, horizontal, flowers pinkish, stigmas much above the anthers. The leaves are very rugose, folded along the lobes, central lobe long, broad often recurved, lateral lobes long and acute, margins coarsely serrated, often waved. Leaf sinus and lobe sinus are deep. The foliage is bright green. The fruit is midseason, small, acid, the skin tough. Very few flowers set.

Rogue Type C. (*Received from two sources.*)

The bushes are very vigorous, erect when young, later very spreading, much branched. The buds are medium to small, conical, greenish and ragged, pointed, stalked and erect. The racemes are of medium length and horizontal. The flowers are pale yellow in colour, the stigmas much above the anthers. The leaves are thin and flattish ; the central lobe is broad but acute, the lateral lobes are irregular and often obtuse. The leaf sinus is intermediate to shallow, the petiole green. Fruit medium in size, rather mild, midseason, skin tough. It yields a very small crop.

Cropping.

The almost total failure of the rogue types to set fruit has already been referred to, and the following table gives an idea of their respective performances when grown under the same conditions as Baldwin.

Average Weight of Fruit per Bush, 1929. (*Five years planted.*)

Baldwin	(10 bushes)	..	64 ozs.
Rogue Type A	(10 ,,)	..	7 ,,
,, ,, B	(10 ,,)	..	4 ,,
,, ,, C	(2 ,,)	..	20 ,,

The yields of the rogue types, all of which produce large vigorous bushes, are shown to be very low when compared with the Baldwin which makes a much smaller bush. The cause of the failure of the flowers to set a crop is at present not clear but as they all possess long styles, bringing the stigmas above the anthers it is probable that lack of pollination (2) is a contributory factor. If this is so pollination of the flowers by hand should remedy the defect, but preliminary trials in this respect have not been successful. Further trials will be made another season and the possibility of internal defects in flower structure will also be investigated in order to find out the underlying cause of the failure to set fruit.

Summary.

1. The practical importance of planting varieties of Black Currants true to name is emphasized.

2. The performance of certain varieties distributed as Baldwin are compared with that variety, and they are shown to be worthless.

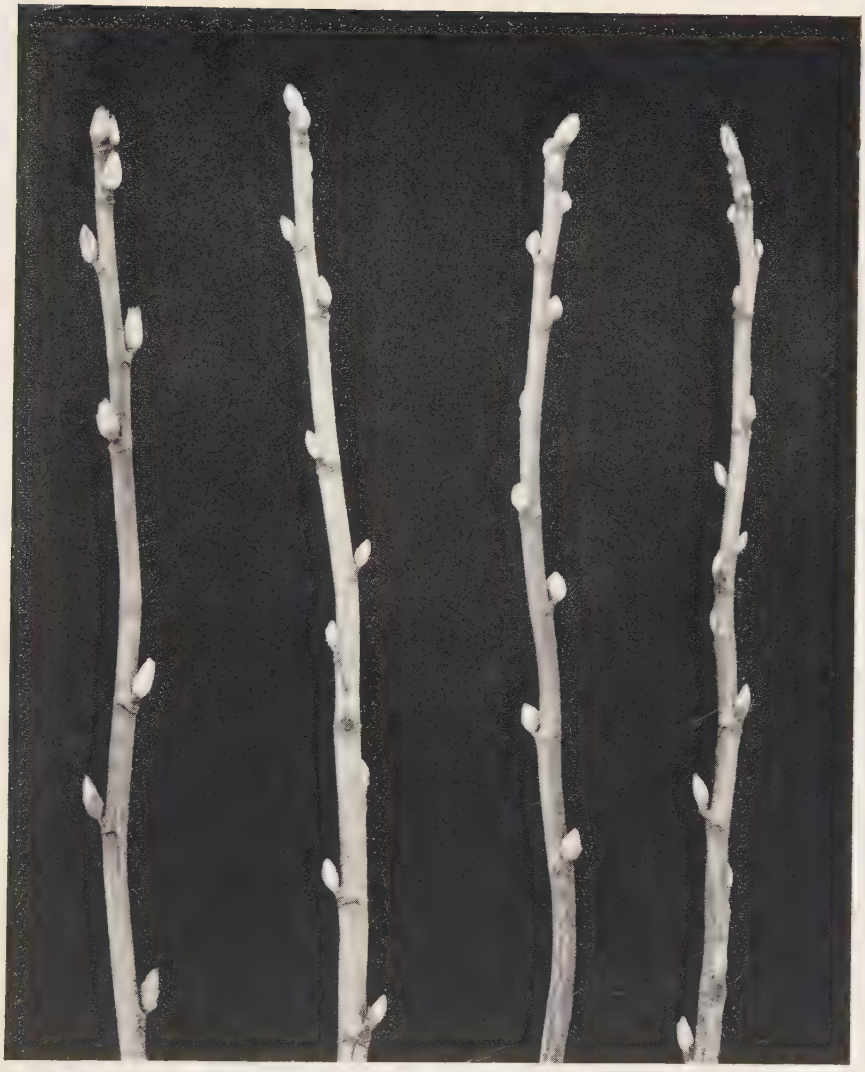
3. Detailed descriptions are given, together with that of Baldwin, as an aid to their identification.

References.

(1) *Hatton, R. G.* Black Currant Varieties—A Method of Classification. Journ. Pom. & Hort. Sci., 1920, **1.** 145-154.

(2) *Wellington, R., Hatton, R. G.,* and *Amos, J.* The Running Off of Black Currants. Journ. Pom. & Hort. Sci., 1921, **2.** 160-198.

Type :	Baldwin's Black.	Rogue Variety A.	Rogue Variety B.	Rogue Variety C.
WINTER CHARACTERS.				
Habit of Growth.	*Dwarf compact bush.*	*Large compact bush.*	*Large compact bush.*	*Very large bush, very spreading.*
Strength of Wood.	Weak.	Weak.	Strong.	Weak, slender.
Wood Colour.	Light buff.	Light buff.	Bright buff.	Pale buff.
Buds.				
Size.	Long and large in relation to stoutness of wood.	*Medium.*	*Large and prominent.*	*Small, often crowded.*
Shape.	Conical.	*Oval.*	*Round and broad.*	*Conical (narrow).*
Apex.	Often pointed.	Acute.	Obtuse.	Very pointed.
Colour.	Light green appearing almost white.	*Dull green slight reddish tinge.*	*Brownish red.*	*Light green, tinged pink.*
Scales.	Loose and ragged.	*Compact.*	*Loosely arranged.*	*Ragged at apex.*
Position.	Very protruding.	Protruding.	Protruding.	*Erect, stalked.*
Season of coming into leaf.	Quite the earliest in leaf.	Early, a little later than Baldwin.	Early, later than A.	Early, but much after Baldwin.
SUMMER CHARACTERS.				
Inflorescence.				
Number of Racemes at node.	Usually two to three.	Usually two.	Usually one.	Usually one.
Length of Peduncle.	Medium.	Medium.	Long.	Rather short.
Pose of Peduncle.	Semi-rigid and wavy.	*Hortizontal, wavy.*	*Horizontal.*	*Horizontal.*
Peduncle.	Short, curved towards base.	Long, curved towards base.	Long, not curved.	Long, curved towards base.
Bracts.	Minute, broad at base.	Small.	Small.	Small.
Flowers.				
Number.	Six to twelve.	Seven to ten.	Ten to twelve.	Seven to nine.
Size.	Medium.	Medium.	Medium.	Medium.
Calyx Tube.	Very light yellow green.	Yellow-green.	Yellow green.	*Pale, yellowish.*
Sepals.	Slightly flushed pink.	Tinged pink.	Tinged pink.	Tinged pink.
Petals	Light yellow green.	Light yellow-green.	Light yellow-green.	Light yellow-green.
Style	Stigmas usually on level. with anthers.	*Stigmas much above anthers.*	*Stigmas much above anthers.*	*Stigmas much above anthers.*



Baldwin. "Rogue," Type A. "Rogue," Type B. "Rogue," Type C.

Winter Shoots, showing bud characters.

Baldwin.

"Rogue," Type A.

Foliage Characters.

"Rogue," Type B.

"Rogue," Type C.

Foliage Characters.

Type:	Baldwin's Black.	Rogue Variety A.	Rogue Variety B.	Rogue Variety C.
Leaf.				
Size.	Medium to small.	Medium to large.	Medium to large.	Medium to small.
Surface.	Flattish, slightly rugose, dark green.	*Flat, rugose edges upturned, often cupped, dull green mottled with yellow.*	*Flattish rugose much raised between veins, latter recurved, bright green.*	*Flat, slightly rugose, thin, in texture, light green.*
Terminal Lobes.	Acute pointed, appearing long owing to short lateral lobes.	*Sub-acute, very broad and short.*	*Long, broad and acute, recurved.*	*Acute, curving downwards.*
Lateral Lobes	Very regular and acute.	*Irregular, short and obtuse often rounded.*	*Regular, medium broad, acute, recurved.*	*Regular, short and acute.*
Serrations.	Noticeably regular and acute.	*Irregular, very coarse, often rounded.*	*Regular, coarsely serrated margins often waved.*	*Irregular, often obtuse.*
Petiole.	Medium to long, pinkish.	Medium, deep red.	Medium to long, pinkish.	*Short, pale green.*
Leaf Sinus.	Usually deep.	Deep, often closed by lobes.	Deep.	Intermediate to shallow.
Lobe Sinus.	Deep.	Intermediate to shallow and very wide open.	Very deep.	Intermediate.
Angle of Petiole.	Twisted.	*At right angles to branch.*	*Twisted, gradual obtuse bend.*	*Curved towards stem.*
Fruit.				
Size.	Good medium size.	Small to medium.	Small.	Medium.
Trusses.	Medium.	Medium.	Long.	Medium to short.
Setting.	Very little "running off."	Almost complete failure to set.	Almost complete failure to set.	Sets a very small crop.
Season.	Late to ripen, hangs late.	Midseason.	Midseason.	Mid season.
Skin.	Very tough.	Very hard and tough.	Very hard and tough.	Very hard and tough.
Flavour.	Somewhat acid.	Very acid.	Very acid.	Somewhat acid.

STRAWBERRY CULTIVATION; STRAIN, TIME OF PLANTING AND DE-BLOSSOMING.

By W. S. ROGERS.

Introduction.

This report gives the results of field experiments on strawberries at the East Malling Research Station from October, 1927, to October, 1930. Most of these experiments are still in progress, and the performance of these plots in future years, as well as the performance of repeated plantings in successive seasons, should modify or confirm the results already appearing. The points under investigation are all of direct practical importance to the grower. After a general description of the modern method of plot planning and experimental technique used, these points will be discussed one by one under the following headings:

(a) Strain (including selection from fruiting parents).
(b) Time of planting.
(c) De-blossoming.

Experimental Technique.

These trials are among the first with strawberries to be planned with a view to statistical analysis of the results. Since a full discussion of the advantages of the statistical method has recently been published (5), it will be sufficient to mention here that by this method it is possible to calculate what proportion of the variation between plots is due (i) to differences in position on the field, (ii) to the different treatments given, and (iii) to the chance errors of the experiment. A single standard error is calculated from (iii) which applies to the whole experiment for that particular record. From this it can be calculated whether the differences between the average yield of each treatment are "significant." That is, whether the odds against the differences being due to chance are more than 20 to 1.

The working of the method in practice can be seen from the following description of the plots:

Trial 1 consisted of three stocks (called Strains A, B and C) of Royal Sovereign, bought from growers, some plants of each strain being planted in autumn (October, 1927) and some in spring (February, 1928), thus giving six "treatments," A Autumn, B Autumn and C Autumn, and A, B and C, Spring. Each of these treatments was subjected to randomized distribution in a block

containing all six treatments. There were six of these blocks, so the total number of plots was thirty-six. Each plot consisted of three rows of 228 plants in the 15 ft. alleys between the tree rows of a young apple and pear stock trial. The plants were 15 inches apart and the rows 3 ft. apart and 4 ft. 9 inches from the tree rows. Each strain therefore occupied twelve plots, half of which were planted in autumn and half in spring; there were thus eighteen comparisons of autumn and spring planting, made up of six plots of A, six of B and six of C. This combining of two or more "factors" or problems (e.g. strain and time) in one trial is a valuable feature of the method since the number of comparisons of any one factor (e.g. autumn and spring planting) is greatly increased thereby, and the larger the number of plots, the smaller the differences which can be shown to be significant.

The plots in Trial 1 were purposely made large (684 plants) to overcome plant to plant variation and to give a good selection of plants for raising future runners. A further trial was planted up the following year, 1928-9 (Trial 2) comparing the runners from the original strains A, B and C (i.e. the second generation of the strain trial) and this time with four different times of planting. This made twelve treatments which, repeated in four blocks, gave forty-eight plots. For each strain there were thus sixteen comparisons and for each time of planting twelve comparisons. These plots were situated in 30 ft. alleys between young trees of other trials. The trees were 15 ft. apart and, as they formed convenient markers for the lines when planting the plots, 60 ft. was chosen as the length of the new plot. This, with the plants at 15 inches, and one plant omitted between each plot, gave forty-seven plants to a row. There were four rows, 3 ft. apart in a plot, making 188 plants to each plot.

It was found desirable to arrange the planting lines so that the pathways between plots came midway between two trees. This avoided the danger of trampling the ground next the trees when the strawberries were picked.

With the randomized blocks some difficulty arises at planting time, since the first dozen plots planted are scattered all over the field, with nothing between, and their position needs to be marked and checked carefully. This also makes cultivation rather a problem. Once the whole area is planted up, however, the whole field can be treated as a unit.

A third generation of the strain trial (Trial 3) was planted in October, 1929, and two extra selections or artificial strains were included. There were eight replicates of each treatment, making forty plots. It was decided to keep the repetition of the time of planting trial separate from the strain trial, and this was combined with a de-blossoming trial in forty-eight plots (Trial 4).

In both of these trials the size of plot was still further reduced to 30 ft. by 15 ft., the four rows having ninety-two plants altogether. This appears to be about the smallest plot which can conveniently be dealt with on a field scale.

The economy of land and plants gained by the use of these small plots rather than the very large ones used at first, is very marked. This reduction in size is only made possible, however, by the use of uniform material.

Trial 1 had 36 plots, with 24,624 plants. Trials 2, 3 and 4 together had 136 plots with 17,120 plants.

Fruit Records.

The plots were picked over as the fruit became ripe, and the crop was weighed to the nearest 0.1 lb. This required eight to ten separate pickings during the season. In the large plots the fruit was picked and weighed in three grades (prime fruit fit for punnets, smaller but sound fruit, and damaged fruit). On the smaller plots, only the total weight of fruit at each picking was taken.

Survey and Measurement of Plants.

It was felt that weight of fruit alone gave a rather incomplete picture of plant performance and that number of plants alive and healthy was a desirable figure to know, so in the first summer a complete plant to plant survey was made, in which each plant was recorded as healthy, weak, diseased or dead, as the case might be. This was further developed in following years into a definite measurement of diameter of each plant across the row by means of a rule fastened at the end of a cane (Fig. 1). The unit at first adopted was a large one, the rule being marked in decimetres (about 4 inches), with an extra .5 dm. beyond the normal zero. Thus all plants between .5 and 1.5 dm. came under division 1 and were recorded as 1 dm. (the mean) and all between 1.5 and 2.5 as 2 dm. In using the instrument, one recorder walked along the row holding the measure just above each plant and calling out the size (plus any appropriate comments) while another wrote the record on a sheet of paper marked in $\frac{1}{5}$-inch squares, giving one square to each plant. Two or more measurings of the same plot were written on successive lines, so that the progress of each plant could be noted.

This large unit of measurement showed large differences in size of plant very well, and was easy to read at a distance, but it is proposed to mark the rule in 5 cm. units for future work, to get still greater accuracy.

The measure is painted black, with white divisions, to lessen the glare when working in bright sunlight.

Discussion of Results.

(a) *Strain.*

The three strains of Royal Sovereign strawberry when bought showed considerable variation in appearance (see Fig. 2), but they were all undoubtedly Royal Sovereign.

FIG. 1.
Strawberry Plant Measuring Rod in Use.

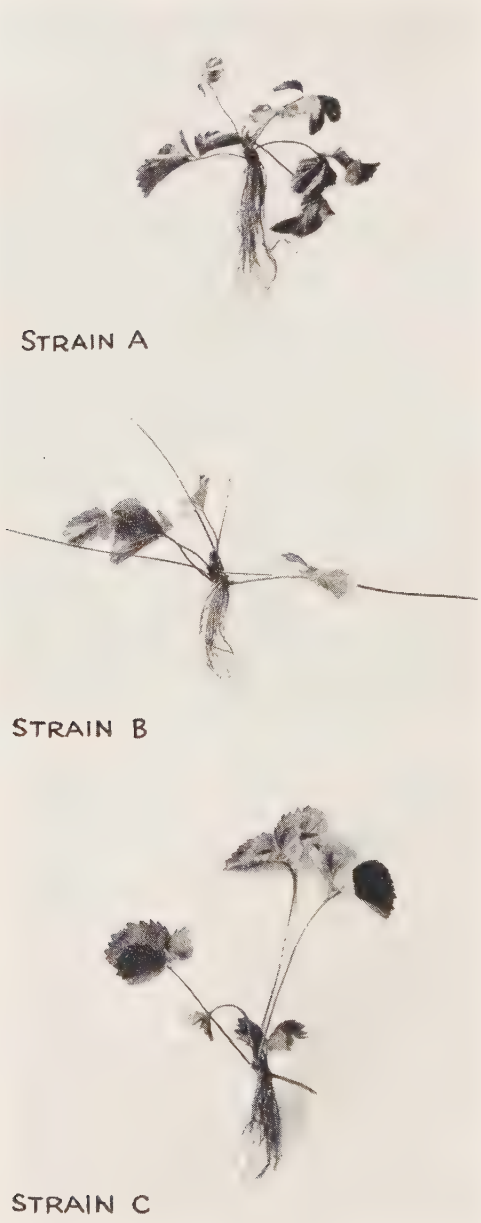


FIG. 2.

Typical plants of 3 Strains of Royal Sovereign Strawberry, as originally received from the growers, showing difference in leaf and root development.

However, a very different performance was given by the different strains in the first year in Trial 1. All the plots were de-blossomed, to get strong runners. The number of blossom trusses taken from two plots of each strain was, A, 2,030 ; B, 1,437 ; and C, 2,607 ; which suggests that the crop on Strain B would have been much below A or C.

A preliminary survey for " Red Plant " (1, 3) was made in May, and a full plant to plant survey was made in July, when all plants were marked as healthy and vigorous, weak or diseased, as described above. Every weak and unhealthy plant was removed.

TABLE I.

Strawberry Strain Trial 1. *First Generation. Vigour, Health and Cropping.*

	Strain A.	Strain B.	Strain C.	Standard Error.	Significant* Difference.
Percentage of vigorous healthy plants. July, 1928	**62.4**	**62.1**	**71.6**	**2.3**	**6.8**
Percentage of Red Plants. May ..	**7.1**	**8.5**	**3.4**	**0.4**	**1.2**
Do. July ..	**5.1**	**6.1**	**2.2**	**0.4**	**1.2**
Crop 1929, cwt. per acre	**12.9**	**10.8**	**13.2**	**0.6**	**1.8**
As Percentage of general mean ..	105	88	107	4.8	14.2

Each figure is the average of twelve plots (of 684 plants), six planted in October, 1927, and six in February, 1928.

* This column gives the variation possibly due to chance.

The results appear in Table I. In number of vigorous, healthy plants, Strain C was significantly better than A or B, and in freedom from red plant C was significantly the best. The observation of this abnormal type of plant was not one of the main objects of the experiment, but the dwarfed reddened petiole was quite distinctive and most of these plants were definitely weak. It will be noted, however, that the amount of red plant observed became less from May to July, and actually the percentage of natural recovery has been high. In later plots the percentage of red plant was very small (about 0.25 per cent.) and this reduction can be attributed to the drastic roguing and careful selection of the runner.

Trial 1 was gapped up, each plot with runners of its own strain, and cropped in 1929 as in Table I.

Here the crop of Strain B is significantly worse than A or C.

In this and following tables the crops are given in hundredweights per acre, and also as percentages of the general mean. That is, the average of all the plots is taken as 100, and each result expressed as so much (per cent.) above or below that. This forms an easy and convenient standard for comparing the relative size of differences.

In presenting these figures it would be possible to give each of the times of planting of each strain separately, but for the sake of simplicity, only the average of all times of planting is given here, and similarly when discussing effect of time of planting, all three strains planted at the same time are added together.

Trial 2, the second generation of the strain trial, consisted of carefully selected runners from Trial 1. These were planted at four different times and allowed to crop in the first year. A complete plant survey and measurement was made as previously described, and the results in vigour and crop appear in Table II.

TABLE II.

Strawberry Strain Trial 2. Second Generation. Vigour and Cropping.

	Strain A.	Strain B.	Strain C.	Standard Error.	Significant Difference.
Crop in first year, 1929. Cwt. per acre	**2.18**	**2.30**	**2.19**	**0.12**	**0.33**
As percentage of general mean	98.0	103.7	98 5	5.3	15.0
Average diameter of plant, August, 1929	**22 cm.**	**23 cm.**	**22 cm.**	**0.03**	**0.08**
Percentage of general mean	98	104	98	1.2	3.5
Percentage of total plants alive	**81**	**80**	**83**	**1.1**	**3.3**
Crop in second year, 1930. Cwt. per acre	**22.0**	**19.9**	**21.7**	**0.8**	**2.2**
Percentage of general mean	104	94	102	3.6	10.4
Average diameter of plant, Sept., 1930 (eight plots of each)	**26 cm.**	**27 cm.**	**29 cm.**	**0.15**	**0.47**
Percentage of general mean	95	99	105	5.6	17.4

Each figure is the average of sixteen plots, four planted in October and December, 1928, and March and April, 1929, respectively.

There is no significant difference in the first year's crop of the three strains. Such difference as there is corresponds exactly with difference in size of plant. Strain B is 6 per cent. superior to A or C in size of plant, and this difference is just significant. It is likely that this difference is due to the fact that the B runners were slightly larger than those of A or C when planted.

In the same year the first generation cropped as two-year-olds, and here Strain B was significantly worse (18 per cent. less) than A or C.

The second crop of Trial 2 (Table II) shows no significant difference between the strains, either on crop or size of plant. (Only half of the plants were measured this time, giving rather a high standard error.)

A third generation of the strain, Trial 3, was planted in October, 1929, with selected runners from special runner beds alongside Trial 2. Besides strains A, B and C, two other selections or " artificial strains " were included, namely,

runners from parents marked as definitely non-fruiting and runners from definitely fruiting parents. These were all from Strain A and were called *Af* and *Anf* respectively. This was to find whether there were non-fruiting strains within the variety. The first year's crop was taken in 1930 and gave results as in Table III.

TABLE III.

Strawberry Strain Trial 3. Cropping.

	A.	B.	C.	Af.	Anf.	SE.	Significant Difference.
First year's crop, 1930.							
Cwt. per acre ..	**6.1**	**6.3**	**5.6**	**5.4**	**4.7**	**0.26**	**0.79**
Percentage of general mean	108	111	100	97	84	4.6	14.1

Each figure is the average of eight plots (of ninety-two plants) planted October, 1929.

As far as Strains A, B and C are concerned, there is no significant difference. Also the difference between the runners from fruiting and non-fruiting parents is not significant. *Af* and *Anf* are both below A (from which both *Af* and *Anf* were taken). This is almost certainly because, in order to get sufficient runners, a rather lower standard of runner had to be taken from the *Anf* parent plants, which were not very numerous. The *Af* runners were chosen as nearly as possible comparable with the *Anf*. One point is clear, that fruit was certainly produced by the *Anf* runners. Actually, practically all of the *Anf* parents fruited in the second year, so it is evident that we were not dealing with permanent or hereditary sterility in this case. Up to the present it can be said that these trials have confirmed the view (4) that different stocks or strains of one variety of strawberry from different sources can give very different performances when brought in to one field, but it appears that if drastic " roguing out " or removal of all but the vigorous and healthy plants is practised, and the runners are carefully selected as was done with subsequent generations in this case, the differences rapidly diminish. This suggests that the environment rather than the clone is the most important factor. Only three strains of one variety were considered in this experiment and, while this statement is quite definite when applied to them, it may not necessarily apply to all strains or all varieties. It seems likely, however, that a good stock can be built up in time from a less valuable stock. But where a grower does not want to spend time and trouble on roguing and selection it is better to get a carefully selected strain in the first place.

(b) *Time of Planting.*

Considerable difference of opinion exists among growers concerning the best time to plant strawberries, and in different parts of the country growers

have reported successful plantings at all periods from June to April. On the whole it seems that winter and spring are the periods that have been commonly chosen in Kent. At Long Ashton (2) and at Botley, Hants (4), very great improvement in crop was reported from August and September planting.

In Trial 1 at East Malling, the autumn planting gave better results than the spring planting. Consequently in Trial 2 it was planned to compare August, October, December and February planting. Some good strong runners were raised and planted out (four plots of each of three strains, as already described) on August 23rd, 1928, under good conditions. During the next four days 0.4 of an inch of rain fell ; September, however, was very dry and the August plants were badly checked. By September 6th only 24 per cent. of them were growing away and these grew so poorly that in April, 1929, these plots were replanted. Only 25.8 per cent. of the August runners were then alive, weighing about 7.2 gm. each, as against 26 gm. each when planted. The plants which replaced them in April averaged about 20 gm. The October and December plantings were carried out successfully, but the planting planned for February had to be postponed till March, as the ground was frostbound.

The first two years' records of size of plant and crop are summarized in Table IV. For simplicity and ease of comparison the weights are given here only to the nearest one-tenth of a cwt., and the measurements to the nearest cm. The results can be compared in three different ways : (1) visually, by the length of the blocks, which are to scale for both years, (2) by the actual figures for diameter of plant or weight of crop, and (3) by these figures expressed as a percentage of the general mean (i.e. taking the average of all plots in the trial as 100). The size of a significant difference is given in figures and is also marked at the end of the blocks by a shaded portion. Hence, if the shaded portions of two blocks do not overlap, the difference between the blocks is significant. If the shaded portions overlap, the difference is not significant.

In Table IV, the month of planting, percentage of plants surviving, crop, and size of plant all appear in the same vertical line. The first year's results are shown in the left half of the table, and the second year's results on the right half.

It will be seen that in this trial, 94 per cent. of the October planted runners survived, but only 76 per cent. and 72 per cent. respectively of the December and April planted runners. This in itself is a matter of commercial importance. The figures for crop are based on weight per plot, irrespective of number of living plants, as being the truest measure of commercial value. The figures for size are, of course, the average per living plant.

The figures for weight of fruit and size of plant show very well the important differences given by different times of planting. The October planted plots have given much the best results, both in size of plant and crop. The first year's crop

TABLE IV.

Trial 2. Time of Planting (1928-29), effect on Vigour and Cropping.

Mean of twelve plots of 188 plants planted in :	Oct., 1928.	Dec., 1928.	Mar., 1929.	Apr., 1929.	Oct., 1928.	Dec., 1928.	Mar., 1929.	Apr., 1929.
Percentage of plants alive. August, 1929	**94**	**76**	**83**	**72**				
	First Year's records, 1929.				Second Year's records, 1930.			
CROP.								
Cwts. per acre	**3.4**	**1.6**	**2.9**	**1.0**	**27.8**	**20.5**	**19.8**	**16.7**
Percentage of general mean	154	74	128	44	131	97	94	79
Standard error	6.1%				4.2%			
Significant difference	17.9%				12.2%			
	Oct.	Dec.	Mar.	Apr.	Oct.	Dec.	Mar.	Apr.
	First Year.				Second Year.			
SIZE.								
Mean diameter of plant. cm.	**26**	**22**	**21**	**19**	**29**	**28**	**26**	**27**
Percentage of general mean	118	100	96	84	107	100	94	99
Standard error	1.7%				6 5%			
Significant difference	4.9%				20.4% (only six plots each).			

The shaded portion represents size of a significant difference . ·. if shaded portions overlap, difference is not significant.

was poor all over, but the October planting produced 3.4 cwt. while the April planting only produced 1 cwt. per acre. The December planting cropped significantly worse than the March, although its plants were slightly, though not significantly, larger than the March ones. This poor performance of the December plants is probably partly due to the severe frosts in the months following their planting. Planting in October gave larger plants than in December and March, and planting in April smaller plants. The second year's records show that the October plants still gave the best results. In fact their increase of 7.3 cwt. over the December plants is a more important commercial result than in the first year (although a smaller relative increase considered as a percentage of the mean).

The crops from the December and March plots do not differ significantly, but the April plants are still behind. In size the plants have evened up considerably in the second year and the differences are not significant. The high standard error is partly due, however, to the fact that it was possible to measure only half of the plots in the time available.

The first year's records of a repetition of the time of planting trial a year later (Trial 4) appear in Table V. This was combined with a de-blossoming trial, discussed below. August planting was impossible this time owing to drought. In the other months, however, a very good stand of plants was obtained. The crop on these plants in their first year was better than in the previous trial, and here again October was best, with 7.1 cwt., and April worst, with 1.4 cwt. The crops from the December and February planting did not differ significantly. The differences in size are less pronounced than in the previous year, but October planting is significantly better, and April planting worse, than the rest.

It will be noticed that in nearly every case the largest plants have produced the largest crops, but the crop has not varied directly as the diameter of plant nor as the square or cube of the radius, suggesting that other factors also are involved.

The results of the different times of planting are clearly connected with weather conditions, notably with rainfall and soil moisture and probably also with sunshine and temperature. Records of these factors are available, but the discussion of them is being postponed until further years' results are seen.

From the commercial point of view, it is evident that it is well worth while to plant as early in the autumn as moisture conditions will allow.

(c) *De-blossoming.*

In Trial 4 the blossom trusses were removed from half the plots on May 23rd, 1930. A survey of the plots with measurements of the plants was taken the following day. A second measurement was made in July, after the fruiting plots had borne their crop. The relative sizes of the de-blossomed and fruiting

TABLE V.

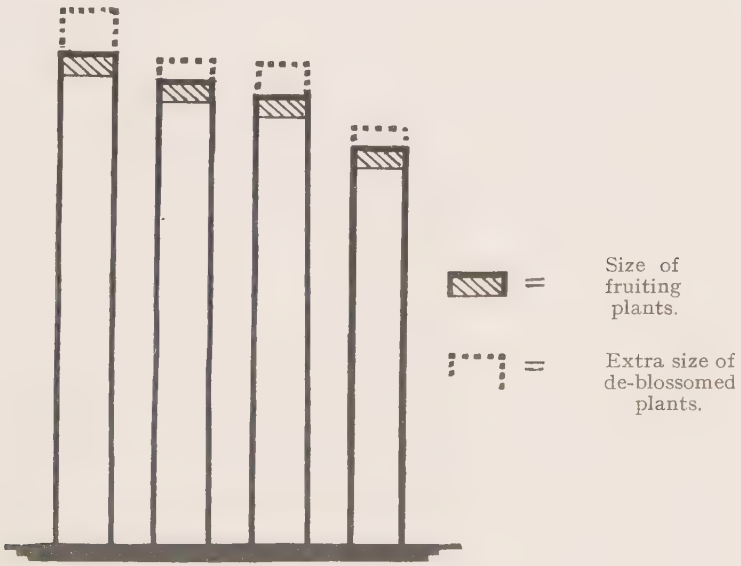
Trial 4. (*a*) *Time of Planting* (1929-30), *effect on Vigour and Cropping.*
(*b*) *De-blossoming, effect on Vigour.*

Average of six plots of 92 plants planted in :	Oct., 1929.	Dec., 1929.	Feb., 1930.	Apr., 1930.	Standard Error.	Significant Difference.
Percentage of plants alive in July, 1930	**97**	**90**	**92**	**96**	**0.93**	**2.7**
Crop, 1930. Cwts. per acre ..	**7.1**	**4.7**	**4.2**	**1.4**	**0.27**	**0.89**
Percentage of general mean ..	163	108	98	32	6.5	20.6

CROP.

Size, July, 1930.						
De-blossomed Plants.						
Diameter cm.	**35**	**32**	**32**	**27**	**0.05**	**0.16**
Percentage of mean	115	104	104	90	1.7	5.3
Fruiting Plants.						
Diameter cm.	**32**	**30**	**29**	**26**		
Percentage of mean	105	100	96	86		

SIZE.



The shaded portion represents size of a significant difference.

plants can be seen in the lower part of Table V. In every case the de-blossomed plants had grown larger than the fruiting plants. The increase in diameter is about 6 per cent., on an average, for all times of planting. As this is in all directions it probably represents an actual increase in effective area of plant of considerably more than six per cent.

A much larger portion of the plants' energy, saved by not having to bear a crop, was put into the production of runners, as can be seen in Table VI. Here the weight of runners, which began to form on all the plots, and which were cut off on June 7th (since the trial was primarily for fruiting), is seen. In every case the de-blossomed plots had a considerably larger weight of runners than the fruiting plots, amounting to an over-all increase of 32 per cent. The much greater amount of runners produced by the earlier planted plots is also very striking. The October planted plots had seven or eight times the amount of the April planted plots. It must be borne in mind that this record is not of actual rooted runners, but of weight of runners cut off. The counting of several samples showed that 1 lb. of runner contained about fifty plants with leaves 3 inches long at that time. Nevertheless it is likely that these weights understate (rather than overstate) the differences, for actually the runners on the early planted plots were much more forward and vigorous besides being more numerous at the time they were cut off.

From the point of view of runner production it is quite clear that both early planting and de-blossoming of the parent plant are of very great value.

Acknowledgments.

The writer is indebted to Mr. T. N. Hoblyn for planning the plots and analysing the records statistically, and to other members of the Staff for helpful criticisms and suggestions in the production of this report.

Summary.

1. Experiments are in progress at the East Malling Research Station to test the effect of strain, time of planting, and de-blossoming of strawberries.

These experiments are among the first with strawberries to be planned on modern statistical lines, by which the significance of the differences can be tested. The first three years' records are discussed in this paper.

2. Three different strains of Royal Sovereign strawberry showing significant differences in the first generation have been made much more uniform in subsequent generations by the elimination of weak and unhealthy plants and by the selection of vigorous runners.

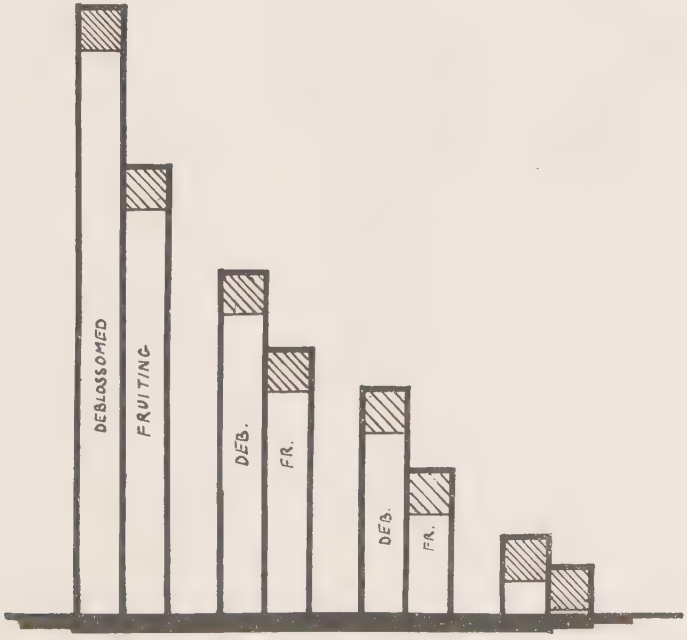
3. Early autumn planting has given much better results than winter or spring planting in size of plant, amount of fruit and production of runners.

TABLE VI.

Trial 4. Effect of Time of Planting and De-blossoming on Runner Production.

Average of six plots planted in :	OCT., 1929.	DEC.	FEB.	APR.	Standard Error.	Significant Difference.
De-blossomed Plants.						
Weight of runners* lbs. ..	**6.4**	**3.6**	**2.4**	**0.9**	**0.16**	**0.5**
Percentage of general mean ..	224	127	84	30		
Fruiting Plants.						
Weight of runners* lbs. ..	**4.8**	**2.8**	**1.6**	**0.5**	5.6	17.4
Percentage of general mean ..	166	98	54	18		

*Runners cut off June 7th, 1930. Per plot of 92 plants.



The shaded portion represents size of a significant difference.

October planting has actually given best results to the present time at East Malling. There was little difference between December and February from the point of view of vigour of plant and fruiting, but the earlier planting produced more runners.

4. The removal of blossom trusses in the first year resulted in a 6 per cent. increase in diameter of plant and a 32 per cent. increase in amount of runners.

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(1) *Ball, E.* Some Observations on Red Plant of Strawberries. Long Ashton Ann. Rept., 1926, p. 73.

(2) *Ball, E.* and *Mann, C. E. T.* Studies on the Root and Shoot Development of the Strawberry, III. Journ. Pomol. and Hort. Sci., 1927, **6.** 87-100.

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RECORDING APPARATUS FOR HORTICULTURAL EXPERIMENTS

INCLUDING AUTOMATIC COUNTING DEVICES.

By W. S. ROGERS.

Very little attention has been given to the design of recording apparatus specially suitable for horticultural experiments, but every research worker knows what a great difference suitable apparatus makes, both in speed and comfort.

This paper gives the results of experience at the East Malling Research Station, under the following headings :

(1) Consideration of desirable points in outdoor recording apparatus.

(2) Description of various measuring and weighing apparatus, and record sheets and holders.

(3) Description of automatic recording apparatus, viz. :

Field telephone measuring apparatus.
Counters.
Recording Secateurs.
Counting Picking Bag.
Apple Grade Counter.

Nearly all horticultural experiments require records involving measuring, weighing, or counting. These are the main records discussed here. There are, of course, numerous special records which need special apparatus and technique (for instance, Colour Grading (2)).

(1) Desirable Points in Outdoor Recording Apparatus.

Apparatus for recording out of doors must be easy and convenient to handle, robust and yet light. The latter point is often forgotten by local carpenters and blacksmiths when asked to make measuring rods, but a few extra pounds weight makes quite a difference to fatigue in a day.

The calibrations should be easy to read at the normal working distance—usually the larger the figures the better. For reading at a distance, black and white are the best colours. White figures on a black ground give least glare, but alternate strips of black and white background help to emphasize the units of measurement.

Of course, the apparatus must be able to withstand moisture. Even if not out in pouring rain it is sure to get wet with showers, or dew from the grass or leaves. It follows that all apparatus should be well painted or varnished.

Of available materials, bamboo cane is perhaps the lightest, but where flat surfaces are required ash or mahogany are most suitable. The soft woods are not very satisfactory for long pieces of apparatus.

Another desirable characteristic is that of folding up into a small space when not in use.

Apparatus used by workmen needs to be considerably stronger than that used only by skilled recorders.

(2) Measuring and Weighing Apparatus.

The large tree-measuring rod used at East Malling is six metres long, marked in tenths of a metre. Alternate metres are painted black and white. The rod is of $\frac{1}{2}$ inch ash, tapering from 2 inches wide at the bottom to 1 inch at the top, and supported at the back by a stay, tapering from $\frac{3}{4}$ inch by $\frac{7}{8}$ inch to $\frac{1}{2}$ inch by $\frac{1}{2}$ inch and fixed on with screws. This girder construction enables a rod even of this length to be sufficiently strong to stand being erected in a wind and yet to be reasonably light.

The same rod is used for measuring branch spread, being laid on the ground against the trunk. The extremities of the branches are marked by two sighting rods consisting of 5 feet bamboo canes. At the bottom of each cane is a triangular piece of wood, on which hangs a pendulum showing when the rod is vertical. This triangle is placed parallel to the measuring rod and a second piece of wood at the top of the cane, at right angles to the other, shows the recorder if he is standing truly at right angles to the measuring rod. (Illustrations in reference 1.)

A special strawberry plant measuring rod is described in another article in this Report (3).

The most satisfactory weighing apparatus for experimental plots is the spring balance, on account of its portability and quick reading. The 20-lbs. " Family " type pan balance is very handy for light work, but it must be stood quite level to be accurate. A better type for field work is the hanging dial type, supported on a tripod (Fig. 1). This reads accurately irrespective of level of ground, and the dial is convenient to read, since it is at eye level. The Salter's M40 type, marked in tenths of a pound, with two hands, one fixed and the other movable, has proved very satisfactory.

The technique of weighing the crops from the strawberry plots (which number some hundreds) at East Malling is worth describing. As the fruit is picked, the baskets from each plot are left beside the plot label. The weigher goes along the row of labels weighing the fruit from each plot in turn.

[*Photo W. S. Rogers.*

FIG. 1.

PORTABLE WEIGHING APPARATUS AND PICKING BAG WITH COUNTER ATTACHED.

[*Photo Special Press.*

FIG. 2.

TELEPHONING TREE GROWTH MEASUREMENTS TO THE RECORDS OFFICE.

[*Photo Special Press.*

FIG. 3.

RECORDING AND ADDING WOOD GROWTH MEASUREMENTS TELEPHONED FROM THE PLANTATION.

[*Photo W. S. Rogers.*

FIG. 4.

THE RECORDING SECATEURS IN USE.

The number of cuts made is automatically counted.

[*Photo W. S. Rogers.*

FIG. 5.

THE COUNTING PICKING BAG IN USE.

Each apple is recorded, on the counter, as it is put into the bag.

If it is found that at a certain picking the plots have, say, about three baskets of fruit each, then, before starting to weigh, four empty baskets are placed on the tray hanging from the balance, and the movable hand (which is red) is then set to zero. On coming to a plot with, say, two baskets of fruit, these are placed on the tray together with two empty baskets (making a total of four baskets) and the *net weight* of fruit is read straight off from the red hand of the balance, so avoiding calculations.

A conveniently marked-out record sheet is a great help. It should be arranged so that successive entries come next to each other as far as possible. This saves much time and avoids possibility of error. Loose leaves are better than bound books. A record sheet drawn out like a plan of the plot is often very convenient.

A good method of holding these sheets is to clip them to a light board by a metal clip at the *top* edge, the bottom edge being held by a spring clip or a rubber band. This is effective even in a wind, and the pages can be turned over the top without tearing.

(3) Automatic Recording Apparatus.

The use of mechanically recording devices leads to a considerable saving in time and trouble. In fact such apparatus often makes possible the obtaining of a record which otherwise could not be taken.

A Burroughs adding machine in the records office connected to the plantation by a portable field telephone has been used for the recording of wood growth measurements at East Malling for the past six years with great success.

The measurer calls out the length of the shoots and the operator indoors simultaneously records and adds them up on the machine. See Figs. 2 and 3 and description of technique in reference 1.

The field telephone consists of a unit of microphone, transformer and headphones, operated by a two-cell dry battery, at each end. Originally a microphone slung on the chest was used, but now a button microphone resting on the cheek has been substituted, as this cuts out outside noises and enables the measurer to be heard without his shouting.

"Electron" steel and copper stranded insulated wire is used, slung from poles or other convenient supports. A hose reel is used for winding the wire at the headland and a smaller reel is used up the rows. Each reel is fitted with interchangeable plugs for rapid connecting up.

The weight of the outside unit is 5 lbs.

Counters are very handy for recording such things as number of blossoms. The reset type, set to zero with one turn of the knob, such as the Veeder AB2, is most convenient. Where objects are being divided into several classes, a

number of counters can be mounted on one board, to count all classes simultaneously.

Perhaps the greatest use of counters is where they can be applied to some routine operation, which has to be carried out in any case, and the operation is thereby made to yield a useful record with little or no extra work. The Recording Secateurs, Counting Picking Bag, and Grade Counters described below, used in the pruning, picking and grading of apples are cases in point.

Recording Secateurs. Recording secateurs (Fig. 4) are a simple and efficient piece of apparatus, by means of which the number of shoots cut off in pruning is automatically registered. The number of shoots is quite a useful record to have, since it gives some indication of the growth each season, and, particularly when supplemented by records of weight of prunings and length of random samples of shoots, it replaces to some extent the laborious direct recording of wood growth.

The actual construction is shown in Fig. 6. Two $\frac{1}{8}$-inch holes are drilled carefully and accurately in the arm of the secateurs, and screws pass through the base of the counter C, the arm of the secateurs S and finally a metal plate P, shaped as shown. This plate acts as a foundation for the nuts, and also as a catch to hold the secateurs closed when not in use.

On the other arm of the secateurs is a spring steel strip, shaped as shown, and held in place by one $\frac{1}{8}$-inch nut and bolt. The counter arm is adjusted so that it reaches the end of its stroke just before the cut is completed. The final fraction of an inch of movement is taken up by the spring. This automatically allows for wear in the anvil and in the bolt of the secateurs.

The counter is set to zero before starting each tree, with the secateurs open.

This apparatus has proved very reliable, and can be used by any ordinary labourer.

The counter used is a Veeder Z13, costing 25s., and Rolcut secateurs, costing 7s. 6d., have proved very suitable. The cost of spring and plate is very small, but skilled work is required for the fitting up.

Counting Picking Bags. When the trees in experimental plantations become large, the work of counting the number of fruits becomes very great indeed. The number of fruits is, of course, a very valuable record, for this, together with the weight of crop, makes it possible to obtain immediately the average weight of a single fruit, which can be used for comparing size of fruit.

The Counting Picking Bag (Fig. 5) was introduced at East Malling in 1930, after preliminary trials in 1929. In this apparatus the action of placing each fruit in the picking bag works a ratchet reset counter, which thus registers the number of apples picked. When the bag is full it is weighed (on a spring balance with movable hand allowing for the weight of the bag, Fig. 1), and then emptied

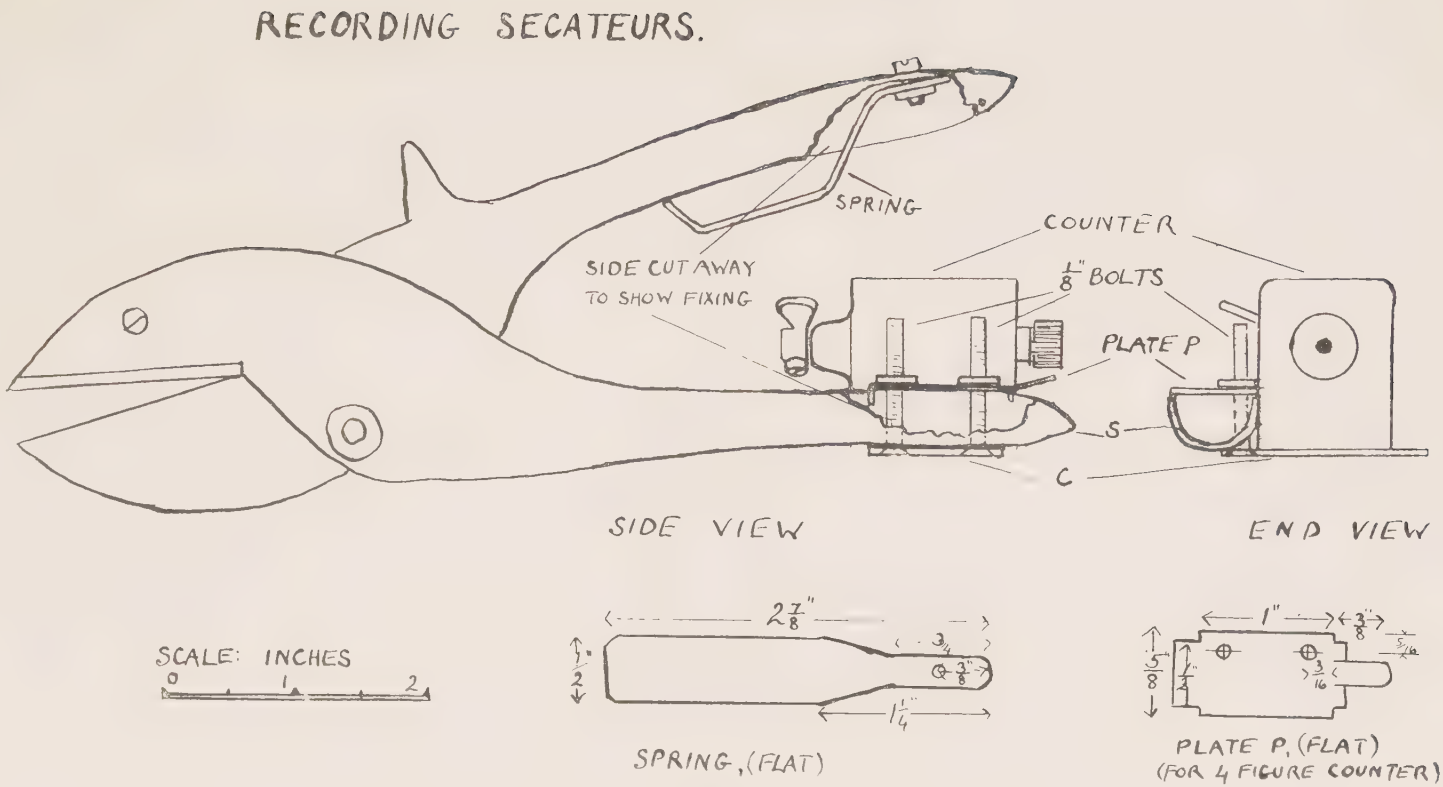

Fig. 6.

DETAILS OF CONSTRUCTION OF RECORDING SECATEURS.

by loosing the cord which ties up the bottom of the bag. If there are still more apples to be picked from the same tree the counter need not be reset until the end of the tree, when the total number of apples can be read off. Alternatively the number at each weighing can be written down, and the counter set to zero.

It is not the weight of the apple, but the movement of the picker's hand in opening the bag, which actuates the counter. Difference in size of apples is allowed for by an arrangement of springs.

The picking bag used was an " Ideal " modified for the purpose. The counter was a Veeder Z13, as used on the secateurs. The counter is mounted on a mahogany block A (Fig. 7), which is bolted to a plywood baseboard B, which also holds a wire framework C. A spring D is fastened at one end to a block E on the baseboard and at the other to the arm of the counter. Fastened to the middle of the spring and pivoting on the wire framework is a strut F, and the whole is covered with a cloth flap. The weight of the spring, strut and flap is taken by a small return spring G, which has one end wired to the counter arm, and the other to the counter guard H. The angle of the counter arm and return spring are important, since this governs whether the counter will work easily even with small apples, and yet not be actuated by the jarring of the picking bag as the picker moves about. Spring D was 10½ inches long, ¼ inch diameter, of 20 gauge wire. Spring G was ¾ inch long, $\frac{3}{16}$ inch diameter, of 25 gauge wire. The strut E helps to guide the picker's hand into the bag. It is necessary to fix a stop as shown to prevent the strut from working out of centre and jamming on the frame. The cloth flap will act as a stop if tied firmly to the frame. The strut is made of light stout tinplate, with the edges turned down to strengthen it.

A hook is fitted at the end of the right hand webbing of the picking bag, to make it easier to put on and take off. Several strips of webbing are slung loosely below the wire frame, to break the fall of the apples and lessen the chance of bruising.

This counting picking bag is perfectly reliable when used with ordinary care. The bag can be used when the picker is on a ladder, but care should be taken not to let twigs catch in the springs. Both hands can be used for picking.

One recorder can write down the numbers and weights for a gang of from six to ten pickers. The weighing tripod is carried round from tree to tree, so the records are actually made at the tree, and no boxes of fruit need be labelled (unless wanted for other purposes).

The picking bag itself costs 10s., and wood, springs, webbing, etc., about 3s. The counters (25s. each) were taken from the recording secateurs. The fitting up was done by the writer.

Grade Counters. On a mechanical grader such as the Cutler Grader, it is not difficult to make the falling of the cradle containing each apple work a counter

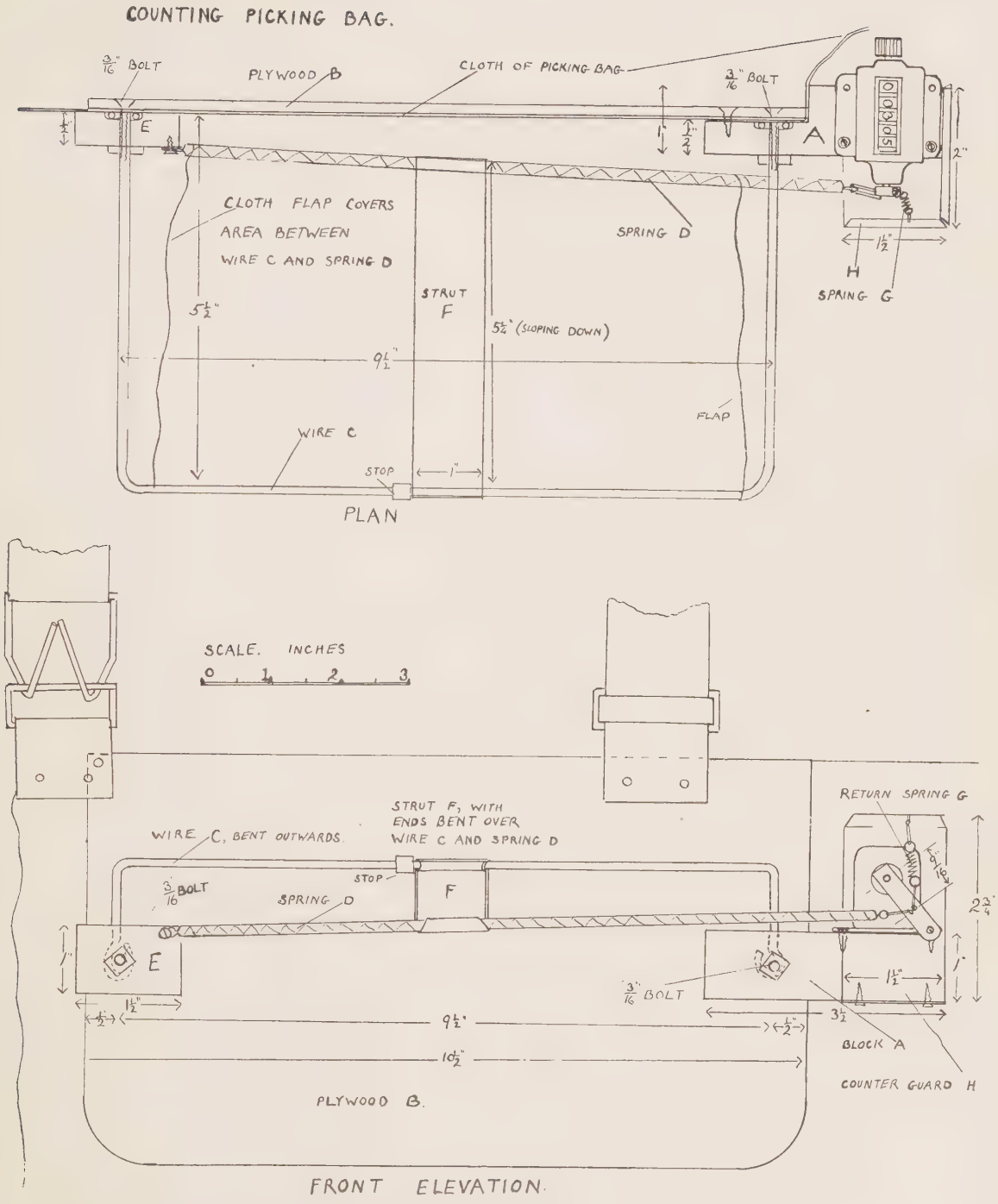

FIG. 7.

DETAILS OF CONSTRUCTION OF COUNTING PICKING BAG.

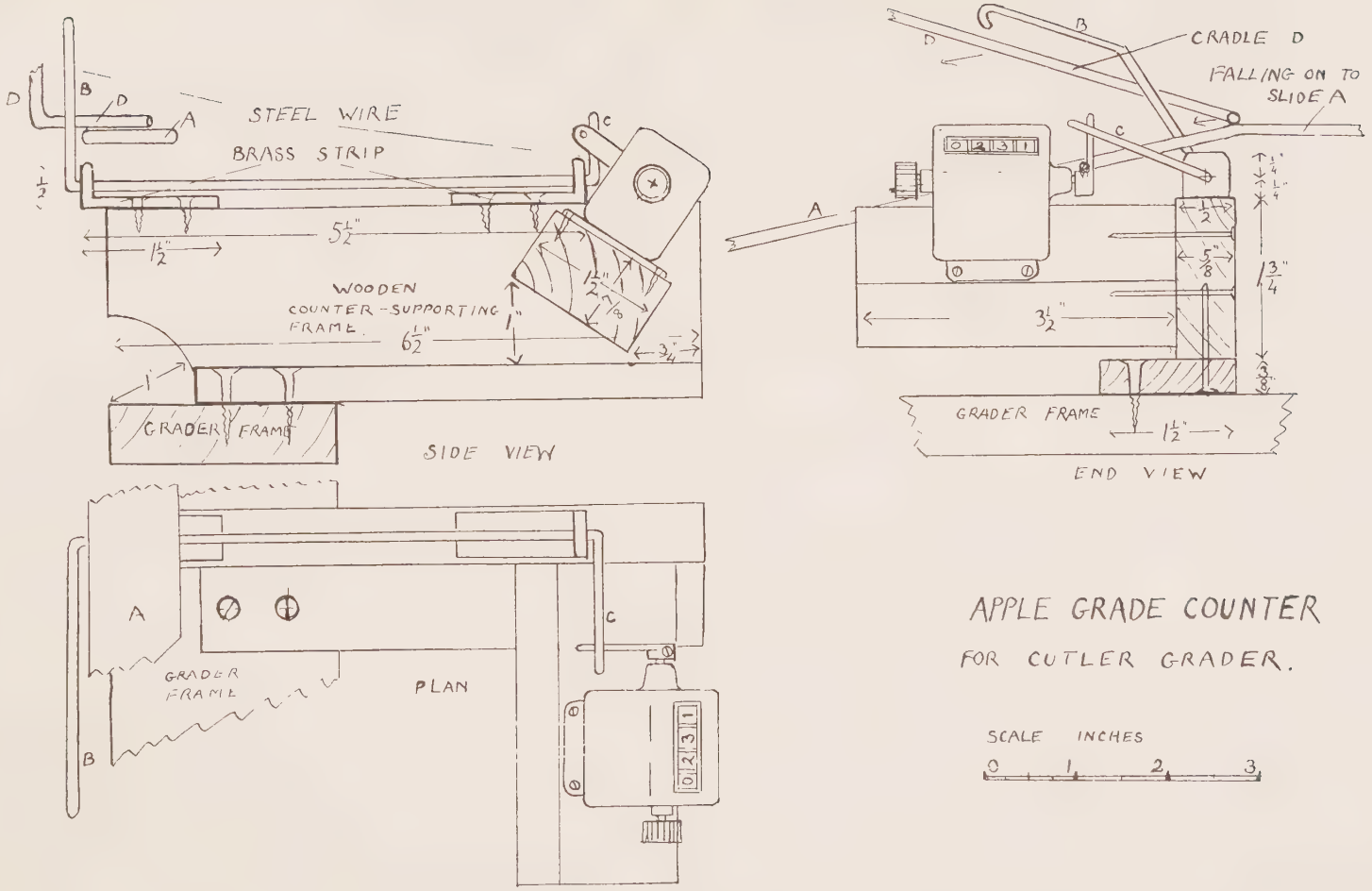

FIG. 8.

METHOD OF ATTACHMENT OF COUNTER TO CUTLER GRADER.

on the appropriate bin. At the end of each lot of apples, the number in each grade is shown on the counter above each bin.

The arrangement adopted is shown in Fig. 8. The falling cradle D moves along slide A, and pulls down the end B of a steel wire supported in brass bearings on a wooden frame as shown (Fig. 8). This makes the other end of the wire, C, push down the arm of the counter. The frame simply holds the counter out over the bin, in a position easy to read. The wire must be fairly light to avoid momentum effects when working at high speed.

These arrangements are the outcome of a fair amount of experiment, but it is probable that they can be improved upon. If each problem is considered in the light of the movements involved, and the variation in the movements, some method of recording any action on a counter can usually be found.

Summary.

This paper discusses desirable points in outdoor recording apparatus. Various measuring, weighing, and counting apparatus and record sheets, and field telephone wood growth measuring apparatus, are described. A full description is given of the construction and use of the following automatic recording apparatus : Recording Secateurs, Counting Picking Bags, and Apple Grade Counter.

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AN EXPERIMENT IN THE THINNING OF VICTORIA PLUMS.

By A. C. PAINTER.

In these days of increasing competition and low market prices for the poorer grades of fruit, anything that tends to improve "Fruit Quality" should merit the careful consideration of the grower.

One of the means claimed to achieve this end by those growers who have made a habit of practising it, is that of Fruit Thinning, and it may therefore not be out of place to give details of an experiment which would seem to give some indication of its possibilities.

Whilst perhaps too much stress must not be laid on a one-year experiment of this nature, it is thought that the results are sufficiently encouraging to make it worth while for growers to test out the matter for themselves.

Material Used.

The opportunity was taken of an exceptionally heavy plum set in the summer of 1930 to carry out at East Malling a small one-year experiment with a view to testing the results of thinning on Victoria plums in a year of glut.

Thirty 10 year planted trees were selected, six on each of the following stocks:—Pershore, Brussels, Common Plum, Brompton and St. Julien seedlings.

All were bearing a heavy crop, large sections of branches having between twenty and thirty, or even more, plums to a foot of wood. The trees were selected in pairs, the members of each pair being on the same rootstock and approximately equally loaded with fruit. One tree of each pair was thinned, the other being left as control. Thus three trees of each stock were thinned and three trees left unthinned, making fifteen of each in all.

The trees are planted at 15 feet apart and interplanted with pears and blackcurrants. The ground has been normally cultivated and has received ordinary commercial manuring suitable for a mixed plantation.

The plums were somewhat small throughout, probably owing to the competition with the pears and bush fruit.

Technique.

The plums were thinned by hand to about 1½ inches apart between the stalks. This work was carried out by women between June 26th and July 3rd.

To obtain an estimate of the approximate number of plums to a tree, the following records were taken :—

(a) At the time of thinning, the total thinnings from each tree were weighed, and at the same time the weight was taken of a random sample of 100 plums.

(b) At the time of picking, a number of random samples of 2 lbs. each were taken from each grade and counted.

When picked, the fruit from the three similarly treated trees on each stock was put together and graded into different sizes, thus giving fruit from five comparable sets of trees.

In any experiment of this nature, though every precaution is taken to get sets of trees as comparable as possible, some differences are bound to occur for which allowance must be made if practicable. In this case, when it came to calculating the total number of plums that had been on the trees before thinning took place, it was found that in nearly every case this was greater for the thinned than for the unthinned trees. Thus the results could not be compared directly as they stood.

To overcome this difficulty the results obtained from the series of thinned trees are simply compared with the probable returns of those trees if they had not been thinned, this probable performance being estimated from the actual crop and prices obtained from the unthinned trees.

No account was taken of dropped fruit after time of thinning, and, though this was not large, it would undoubtedly be greater in the case of the unthinned trees. Had this been done, there would have been a relatively greater number of fruits on the unthinned trees which would have had the effect of enhancing the results in favour of the thinned trees.

Number of Plums Removed at Thinning and Time of Marketing.

The approximate numbers of plums removed from the thinned trees at time of thinning and at marketing were as follows :—

	Removed at Time of Thinning. Average per tree.	Picked at Time of Marketing. Average per tree.	Proportion of Crop removed at Thinning.
Three trees on Pershore	2,670	1,790	60%
Three trees on Brussels	2,540	1,800	59%
Three trees on Common Plum ..	3,270	1,900	63%
Three trees on Brompton ..	4,540	2,830	62%
Three trees on St. Julien ..	4,160	2,000	68%

Thus on an average some three plums in every five were removed at time of thinning.

TABLE I.

Yield of Fruit (three trees in each case).

On Root-stock.	Approx. total number of Fruits gathered at picking.	Selected.		Grade 1.		Grade 2.		Grade 3.		Small.		Very Small.		Wastage.		Total.		Total Return.
		lbs.	Net Ret.	lbs.	Net Ret.	lbs.	Net Ret.	lbs.	Net Ret.	lbs.	Net Ret.	lbs.	Net Ret.	lbs.	Net Ret.	lbs.	Net Ret.	
			s. d.		s. d.		s. d.		s. d.		s. d.		s. d.		s. d.		s. d.	s. d.
PERSHORE.																		
Thinned.	5,400	1.6	4	26	3 8	80	7 4	108	3 9	47	5	26	—	4	—	293	15 6	—
								Loss on handling very small fruit					1				1	15 5
Unthinned.	13,400	—	—	1	3	22	2 9	111	4 10	143	1 8	142	—	28	—	447	9 6	
								Loss on handling very small fruit					6				6	9 0
								Difference in favour of the 3 thinned trees										6 5
BRUSSELS.																		
Thinned.	5,400	0.5	. 2	16	2 9	69	7 0	101	3 9	53	7	37	—	6	—	282	14 3	
								Loss on handling very small fruit					2				2	14 1
Unthinned.	13,000	1	3	4	7	46	5 0	132	5 7	144	1 6	125	—	36	—	488	12 11	
								Loss on handling very small fruit					5				5	12 6
								Difference in favour of the 3 thinned trees										1 7
COMMON PLUM.																		
Thinned.	5,700	6.5	1 5	28	4 2	73	6 9	107	3 8	41	5	29	—	13	—	297	16 5	
								Loss on handling very small fruit					1				1	16 4
Unthinned.	15,500	—	—	4	8	45	4 4	151	6 1	155	1 10	145	—	27	—	527	12 11	
								Loss on handling very small fruit					6				6	12 5
								Difference in favour of the 3 thinned trees										3 11
BROMPTON.																		
Thinned.	8,500	2.5	6	25	3 4	83	8 7	153	6 1	77	1 0	57	—	22	—	420	19 6	
								Loss on handling very small fruit					2				2	19 4
Unthinned.	22,100	—	—	1	2	26	2 8	118	5 11	191	2 9	370	—	21	—	727	11 6	
								Loss on handling very small fruit					1 3				1 3	10 3
								Difference in favour of the 3 thinned trees										9 1
ST. JULIEN.																		
Thinned.	6,000	3.7	10	27	4 2	77	7 5	119	4 9	47	4	32	—	11	—	317	17 6	
								Loss on handling very small fruit					1				1	17 5
Unthinned.	18,500	2.4	6	15	2 3	43	3 9	165	5 7	219	2 6	210	—	40	—	694	14 7	
								Loss on handling very small fruit					9				9	13 10
								Difference in favour of the 3 thinned trees										3 7

NOTE.—The fruit shown under the heading of " very small " was found to be unmarketable. This had, however, to be handled with the remainder, and the cost of doing so has been put at 1d. per half sieve of 24 lbs., though in practice it was found to be actually considerably more. It has been thought better, however, to err on the moderate side and not to put it unduly high.

Effect on Size and Market Value.

The trees were picked over twice (on August 29th and September 4th) and cleared at a third picking on September 10th. In each case the fruit was graded by eye into five size grades and marketed under those grades. Table I shows the yield of fruit together with the net return received. (In calculating the net returns deductions have been made on account of grading, packing, transport and other marketing charges, but not on account of picking. Details of these charges are given in the Appendix, as they may be of interest to growers.)

It will be seen that the thinned trees in each case gave an increased net return over the unthinned as follows :—

Three trees on Pershore	6s. 5d. or	£20 7s.	per acre of 193 trees.
Three trees on Brussels	1s. 7d. or	£5 2s.	,, ,, ,,
Three trees on Common Plum	3s. 11d. or	£12 11s.	,, ,, ,,
Three trees on Brompton	9s. 1d. or	£29 9s.	,, ,, ,,
Three trees on St. Julien	3s. 7d. or	£11 11s.	,, ,, ,,

i.e., a total of fifteen trees giving an average increased net return of 1s. $7\frac{2}{5}$d. per tree, or £15 16s. per acre.

An examination of the table at once reveals two outstanding features :—

(1) That, though the total yield of fruit harvested from the thinned trees was in every case very much less than that from the unthinned, this was more than compensated for by the larger yields in the bigger grades and the higher returns received for the fruit.

(2) That by far the greater proportion of the crop in the case of the unthinned trees was confined to the " small " and " very small " grades of fruit, which brought in relatively little or no return.

This low grade fruit, the handling of which involved a considerable amount of time and labour, was, to a large extent, eliminated by the process of thinning, thus setting free labour for other purposes at a very busy time of year.

The manner in which thinning reduces the amount of fruit to be handled at harvesting is well illustrated in Tables II and III, which also show the average net return per half sieve of 24 lbs. in relation to the total crop picked.

Thinning reduced the number of fruits to be handled by considerably more than one half, which means in all probability that in such a case it will only take about half as long to deal with the crop from the thinned trees.

Growers will realize what this means when there are large quantities of fruit to be dealt with.

Though no allowance has been made for quality in assessing its market value, the general appearance of the fruit from the thinned trees was almost invariably better than that from the unthinned, as it was generally of a brighter colour, whilst much of that from the latter was of a dull muddy red.

TABLE II.

Thinned Trees.

Sets of 3 Trees on	Approx. No. of Fruits Picked at Time of Marketing.	Weight.	Average Net Return per Half Sieve of Total Crop Picked.	Total Net Return.
		lbs.	s. d.	s. d.
Pershore ..	5,400	293	1 3	15 5
Brussels ..	5,400	282	1 2	14 1
Common Plum ..	5,700	297	1 4	16 4
Brompton ..	8,500	420	1 1	19 4
St. Julien ..	6,000	317	1 4	17 5
TOTALS, 15 trees	31,000	1,609 or 67 half sieves	1 3	82 7

Equivalent to a net return of £53 per acre.

TABLE III.

Unthinned Trees.

Sets of 3 Trees on	Approx. No. of Fruits Picked at Time of Marketing.	Weight.	Average Net Return per Half Sieve of Total Crop Picked.	Total Net Return.
		lbs.	s. d.	s. d.
Pershore ..	13,400	447	6	9 0
Brussels ..	13,000	488	7½	12 6
Common Plum ..	15,500	527	7	12 5
Brompton ..	22,100	727	4	10 3
St. Julien ..	18,500	694	6	13 10
TOTALS, 15 trees	82,500	2,883 or 120 half sieves.	5¾	58 0

Equivalent to a net return of £37 per acre.

Cost of Thinning.

Against the increased returns, however, must be put the additional cost entailed by the thinning. This has been difficult to estimate. Under our experimental conditions where care has to be exercised to obtain an even thinning of the fruit so as to interfere as little as possible with other experiments in hand, the cost of the work, done by women who had had little previous experience, worked out at about 1s. 9d. a tree (this included a man's time for supervision, moving ladders, etc.). Under commercial conditions, however, it is not thought that this would have exceeded a maximum of 1s. to 1s. 3d. per tree.

In deciding what part of this sum should be charged against the increased returns, it must be remembered that the fruit has in any case to be picked some time or other and that every plum removed at time of thinning means one less to be picked when the crop is marketed. In the case of the trees in question—as has already been shown—some three plums out of every five were removed at thinning, thus leaving considerably less than one-half of the original crop to be harvested, and it is therefore obvious that the cost of picking thinned trees for market is very much less than if they had been left unthinned.

When this is taken into consideration it seems that if the sum of 6d. or 7d. a tree were charged up as the *extra* cost entailed, this should prove to be a sufficient margin.

Thus allowing the sum of 7d. per tree, the cost of thinning per acre works out at £5 13s. Deducting this from the figure of £15 16s., previously arrived at, this still gives a net return of £10 3s. per acre in favour of the thinned trees apart from any considerations of quality or damage done to the trees, which has been discussed elsewhere.

It has been presumed that the trees would be picked over two or three times and not merely stripped at one picking.

The method adopted in arriving at this figure has been gone into in some detail, as it is realized that it may be a matter of some importance in deciding whether thinning is worth while or not, and it is moreover a matter which every grower must consider for himself.

Effect on Tree.

All the trees were well shored up with poles to prevent branches being broken down by the weight of fruit. Strong winds were, however, experienced both in July and August with resultant damage in the plantations. A record

taken of the damage done to the trees used in this experiment showed the following results :—

Tree No.	Stock.	Thinned tree. Branches broken down.	Corresponding unthinned tree. Branches broken down.
1	Pershore.	No damage.	2 large branches.
2	,,	1 small.	1 large and 3 medium.
3	,,	No damage.	1 large and 1 medium.
4	Brompton.	,,	1 large.
5	,,	,,	1 large and 1 medium.
6	,,	2 small.	1 large and 3 medium.
7	St. Julien.	No damage.	5 large branches (i.e., half the tree).
8	,,	,,	3 large and 1 small.
9	,,	,,	3 medium.
10	Brussels.	,,	3 large.
11	,,	,,	No damage.
12	,,	,,	4 small.
13	Common Plum.	,,	1 small.
14	,,	8 small.	2 small.
15	,,	No damage.	1 medium.

It will thus be seen that while the damage done to the thinned trees was practically negligible, the unthinned trees, which were bearing a much heavier weight of fruit, suffered severely and this must almost certainly have some effect on their future yield. This is quite apart from any possible effect of the strain on the unthinned trees of carrying a breakdown crop and the risk of infection by the Silver Leaf fungus through the broken branches.

The writer would like to express his indebtedness to Mr. W. R. N. B. Barnett, who supervised the actual thinning of the fruit, and to Miss R. F. Stern who superintended the picking and grading and took the detailed records of the damage done to the trees.

Summary.

1. A one year experiment on the thinning of Victoria plums in a year of heavy set is described, which, under the conditions obtaining, gave

(a) a definite increase in the size of the fruit on the thinned trees.

(b) a definitely higher net return for the fruit, in spite of a much lower aggregate yield.

2. The cost of thinning is discussed.

3. Most of the crop from the unthinned trees consisted of low grade fruit of little or no market value. This was largely eliminated by thinning.

4. Whilst labour has to be found for thinning, there was a considerable saving of both time and labour when it came to the picking and marketing of the fruit.

5. Whilst wind damage was almost negligible in the case of the thinned trees, considerable damage was done to the unthinned trees.

Appendix.

Cost of Grading and Marketing.

The fruit was marketed in different packages according to quality, the "Selected" and Nos. 1 and 2 grades being packed in 12-lb. chips, grade 3 in half sieves and "Smalls" in bushels.

To enable a ready comparison to be made, the cost of marketing 24 lbs. of fruit in each case has been given.

Cost of Marketing 24 lbs. of Fruit.

	Selected in 12-lb. chips.		Grade 1 in 12-lb. chips.		Grade 2 in 12-lb. chips.		Grade 3 in ½ sieves (of 24 lbs.).		Small in Bushels (of 48 lbs.).	
	d.		d.		d.		d.		d.	
Grading	1.0		1.3		1.3		2.0		3.0	
Rail Charge	6.5		6.5		6.5		3.5		3.5	
Cost of Package	7.6		7.6		7.6		0.9		0.6	
Handling and Cartage	0.7		0.7		0.7		0.5		0.5	
Salesman's Commision (Average)	6.7		4.6		3.5		6.0		4.0	
Total cost per 24 lbs. of Fruit	22.5		20.7		19.6		12.9		11.6	
	Gross.	Net.	Gross.	Net.	Gross.	Net.	Gross.	Net.	Gross.	Net.
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
Market Price per 24 lbs. of Fruit										
29 Aug.	6 0	4 3	4 0	2 4	3 0	1 5	1 3	2	1 0	½
4 Sept.	8 0	6 1	6 0	4 3	4 0	2 4	2 0	11	1 3	3
10 Sept.	8 0	6 1	5 6	3 9	4 9	3 1	2 9	1 8	1 6	6
Size of Fruit (Approx. No. to 1 lb.)	8–10		11-12		13-15		16-20		24-32	

Notes.

(*a*) *Grading.*—The actual cost of grading the plums for this experiment is given, but it worked out somewhat higher than usual as greater care had to be exercised to get the grading even. The proportional cost, however, would be the same in any case. As the cost of grading the smaller plums is very much

higher it is obvious that the fruit from the unthinned trees is much more expensive to grade than that from the thinned.

The time occupied in grading depends more on the *number* of plums to be handled than on the weight.

See also further remarks below.

(*b*) *Rail Charges.*—The charges in the case of the chips are at passenger rates and the bushels and half sieves at goods rates.

(*c*) *Cost of Package.*—This in the case of the half sieves and bushels consists of cost of lining paper and sticks and transport charges of empties from salesman to farm.

(*d*) *Handling and Cartage.*—Represents the cost of doing up the package and cartage to station.

(*e*) *Salesman's Commission.*—In the case of the chips this varies with the market price. In the case of the half sieves and bushels it was 6d. and 8d. respectively. In this connection it must be remembered that salesmen's charges differ from market to market and from one salesman to another.

Though many growers would doubt the necessity of grading the fruit into so many size grades, it is thought that in practice it justified itself and that the prices made, considering the glut of fruit, must be considered satisfactory. Apart from the " small " grade (marketed in bushels) only a few half sieves of grade 3 fruit in one consignment fetched less than 2s. a half sieve and the better grades very much more than this.

No ungraded fruit was marketed with which a direct comparison can be made though growers can possibly compare prices with their own returns.

Grading is not an expensive matter—it is more a question of finding the labour. In grading consignments of plums from thinned trees, where the amount of small fruit was not unduly high, it has been found that four women can grade a ton of Victoria plums by hand in about four hours, which represents a cost of approximately 1d. per 24 lbs. It is suggested that thinning, by reducing the quantity of fruit to be handled at picking, will release labour that the grower might profitably employ for the purpose of grading.

Section II

Physiology

COURSE OF GROWTH IN AN APPLE STOCK DURING THE MAIDEN YEAR.

By M. C. VYVYAN.

Introduction.

Knowledge of the relative magnitudes of the effect of different rootstocks on the vegetative performance of trees has been gained mainly from annual determinations of shoot length, girth and other stem characters, made during the winter months. Where many measurements must be made, and much time therefore required, this is the only practicable time at which to make them, for it is the only period in the year when all the trees can be safely looked upon as being in the same state for several months on end. Differences in stem length between trees measured respectively in December and February will not be due to changes in the trees during the interval of time between the two sets of measurements. During the summer period of active growth, on the other hand, differences shown by trees measured even a fortnight apart may be due largely to growth that has taken place during that fortnight.

It is highly desirable to know how the various types of rootstock bring about their characteristic effects upon the performance of the tree. Apart from the light such knowledge might throw on the special suitabilities of the various stocks for various scions and for different local and cultural conditions, it would be of great value to the experimenter engaged in testing out the effects of new types of stock.

It is important that the number of stocks recommended for general use should be as small as is consistent with the varied requirements of different scions, different soils and different cultural treatments. But if the number of stocks is to be limited thus, it becomes all the more important that these should be the best in every way for their special purposes. There is no limit to the number of new stocks that can be raised by crosses between those already known, and it should be possible by such means to combine in a few stocks the good qualities of several. Our knowledge of the respective effects of existing stocks, however, has been obtained by investigations spread over several years and involving many trees and a considerable acreage of ground. To carry out similar investigations on several hundred stocks—and several hundred have already been raised—would therefore be quite impracticable on account of the cost of labour and land required. It is very desirable, therefore, to find some short cut that will give at least a strong indication of the effect that a new stock is likely to have and give this in a short space of time and in a small piece of land,

such as a nursery row. In this way it would be possible to weed the new stocks down to a small number of the more likely types, which could then be submitted to a full investigation on a larger scale. The best prospect of attaining this end would appear to lie in finding some easily recognizable morphological, physiological or biochemical character, either in the stock or in the scion worked thereon, that is always associated with, from the earliest stages in development, a particular type of stock effect.

Although the dormant season is the most convenient time for measuring the dissimilarities between trees of different composition or different treatment, it is not necessarily the best time for determining how these dissimilarities are brought about. For the investigation of this problem, successive measurements made during the period of active growth would seem to offer better prospects of success, for it is then that the divergencies in the rates or modes of growth, leading to those dissimilarities, can be followed and analyzed. Moreover, the very state of dormancy, so convenient from one standpoint, is a disadvantage from another; the leaves are absent, and these form one of the important feeding organs of the tree. The total amount of growth made by a tree must be largely influenced by the amount of carbon fixed by the leaves, and this in its turn will be determined by the amount of leaf surface, its efficiency per unit surface and by the length of time it is borne by the tree. Some idea of the number of leaves borne by a shoot and of their distance apart may be obtained by counting the nodes and by measuring the internodes in the dormant twig, but there is evidence that some varieties have larger leaves than others, and there is a possibility that stock may influence the size of leaves. Moreover, since the leaf acts as a feeding organ throughout most of its life—though its efficiency may change—a shoot or spur that develops a large leaf surface early in the season and then ceases to grow may contribute more food to the tree than a shoot or spur of the same final size and leaf surface which develops that leaf surface later in the season, for in the former case the leaves will be at work for a longer period. At present, however, it would be impossible to distinguish between the two shoots or two spurs by examining them in their winter condition. There is evidence, moreover, that the stock may influence not only the time of bud-burst on the scion in spring but also the length of the period of shoot growth.

If little can be learnt about leaf relations by study of the shoots in their dormant condition, still less can be discovered about the roots; yet these form the other important feeding system of the tree. It is the stock, moreover, that supplies the root system to the tree, while the scion provides the stems and leaves; it is probable, therefore, that the primary cause of the dissimilarities between the effects of the different stocks lies in some morphological, physiological or biochemical dissimilarities in their respective roots. This does not exclude the possibility that it may be found easier in practice to discover

dissimilarities in the functioning of the roots by deduction from their effects on the shoots than from direct investigation of the roots.

A considerable amount is known, and has been published from this Station, about the differences in the forms of the root systems of the various apple stocks, but little is known about their relative rates of growth or times of growth. This lack of knowledge is due to the difficulty in making even the roughest examination of the roots of a growing tree without checking its growth. Something can be done by growing the trees with the soil and roots against a wall of glass, but where quantitative measurements of a root system as a whole are required, each determination has to be obtained from a fresh set of trees. To follow root growth from month to month, large numbers of trees are therefore required and the work is both laborious and expensive.

In view of these considerations, it was decided in 1928 to supplement the large scale pomological investigations, from which so much has been learnt about the effect of stock on scion performance, by a series of small scale investigations of a more intensive type on specially selected groups of stocks and scions. For this purpose, it was proposed to adapt the ordinary physiological methods of growth analysis, which have been elaborated mainly in work on annual plants, to a study of the development of apple trees. These investigations fall into two groups.

First there are those that are concerned solely with the leaves and shoots, and follow the respective effects of scion and of stock on leaf size, on the distances between the leaves, and on the time of their development, together with the relation of differences in these characteristics to total shoot growth and to blossoming. These investigations can be carried out without damaging the trees, hence the successive measurements can be made on the same set of trees; moreover, they can be made on trees that form part of other experiments.

In the second place there are investigations that involve examination of the roots, the determination of their rates of growth at different times of the year, and the relation of these to the rates of growth of the shoots. In these investigations separate batches of trees are required for each determination, a large number of trees are therefore required, and they cannot be used for any other purpose. When using this "sampling" method, it is essential that each sample should be representative of the "population" from which it is drawn, for it has to be assumed that all the trees not lifted are in the same condition as those lifted as a sample. The reliability with which a sample depicts the general condition of the remaining trees, depends on the variability of the trees and on the size of the sample; the more uniform the material, the smaller will be the sample required. Moreover, it is possible to estimate the degree of accuracy with which a sample fulfils its purpose by measuring the variability within the sample, provided this variability can be relied upon as a measure of the

variability in the general population of trees. It is necessary, therefore, in work of this sort, to use material as uniform as possible and to arrange the sampling so that variation due to soil and other factors may be reflected in each sample.

The investigation, of which this is the preliminary report, belongs to the second group; it is an investigation of the normal course of root and shoot growth of an apple stock throughout the season. Up to the present, only the growth during the "Maiden Year" has been followed.

Material Used and General Plan of the Investigation.

As little was known about root growth in even an unworked stock, there seemed little object in complicating the issue by the use of worked trees or of trees of more than one composition. Unworked shoots from the stool bed of a clone apple stock—Malling No. XIII—were therefore used. This stock was chosen because of its known vigour and good rooting power.

The general plan of the experiment can be stated in a few words; a large number of trees were planted in spring, and samples of fifty of these dug up at intervals during the year. The difference between the mean weights of the trees at two successive "harvests" provided a measure of the amount of growth that had occurred during the intervening period; the distribution of growth between roots, leaves and stems was determined by weighing these organs separately.

The investigation was started in the spring of 1929 with 500 trees which were dug up in batches of fifty during the succeeding twelve months; the last two batches being lifted together as the ninth harvest, in March 1930. It was repeated, with slight alterations, in 1930, but with double the number of trees, so that the harvests might be spread over two years instead of over one.

The trees planted in 1929 were rather small, and were without laterals; the stems were not cut back before planting, but all the roots were removed, in order to make the estimation of new root growth easier. This treatment did not seem too drastic, as No. XIII usually roots well when treated thus. Each tree was given a serial number and was weighed to the nearest .1 of a gramme before planting, and the planting was done in consecutive order; the initial weight of each tree subsequently lifted was thus known. Owing to a bad season there were many casualties, and no sample was composed of its full quota of fifty living trees.

The 1930 trees were much larger than those used in the previous season, they were the thousand best trees selected from ten times that number. Being larger, they bore laterals; these were trimmed off and the main stems cut back to about 2 ft. 6 ins. before weighing. On account of the casualties during the previous season, the roots were left on, but the longer ones were trimmed back to about 6 inches. To get an estimate of the amount removed by these various

operations, and of the amount of root left on, an initial sample of fifty trees was taken at the time of planting. Each of these was treated in the same manner as those planted, but the weight removed in the processes of cutting off the laterals, cutting back the stem and root trimming, were respectively determined. The remaining roots of each were then removed, and the fresh and dry weights of these and of the stems determined. Six further harvests have already been taken during 1930; the last of these was in December.

In both the 1929 and the 1930 investigations the plots were divided up, and the samples randomized, so as to make a statistical estimation of the effect of soil variation possible. This problem is not dealt with in the present paper, so the detailed description of plot lay-out is omitted.

Measurements made on Lifted Trees.

Each tree was washed free from soil and the excess water mopped off or allowed to evaporate; it was then weighed to the nearest .1 of a gramme. The

Table I.

1929-30 *Investigation.*

Fresh Weights of the trees at the time of planting and at time of lifting, also the Dry Weights of the various organs at time of lifting.

Harvest No.	Date when lifted.	Number of Trees.	Mean Total Fresh Weights.		Mean Dry Weights.				
			When planted.	When lifted.	Old Stem.	Roots.	Leaves.	New Stems.	Total* New Shoots.
	1929								
I	4 June	43	10.00	11.99	5.402	.104	.210	.005	.283
			.581	*.595*		*.0092*			
II	1 July	32	10.17	14.90	5.680	.345	.621	.029	.778
			.625	*.813*		*.0377*			
III	22 July	35	11.23	17.96	6.584	.541	.940	.086	1.199
			.799	*1.003*		*.0545*			
IV	19 Aug.	34	11.16	19.34	6.734	.646	1.107	.114	1.434
			.617	*.904*		*.0569*			
V	3 Oct.	32	11.00	23.67	8.079	1.112	1.383	.294	1.961
			.706	*1.650*		*.1185*			
VI	30 Oct.	31	10.38	24.30	8.224	1.628	1.397	.317	1.975
			.896	*2.071*		*.1839*			
	1930								
VII	2 Jan.	40	12.37	22.11	9.494	1.456	Leaves	.372	.372
			1.151	*1.718*		*.1695*	fallen.		
VIII	24 Feb.	38	10.83	20.88	8.263	1.316		.429	.429
			.561	*1.302*		*.1031*			
IX	28 Mar.	73	10.22	20.09	7.743	1.213		.425	.425
			.259	*.702*		*.0766*			

The values in italics are the standard errors.

* The values for total new shoots include the weights of the leaf stalks and unexpanded leaves; these are not included in the values for the leaves.

mean values of these weights are given in the fifth columns of Tables I and II under the heading "Mean Total Fresh Weight, When Lifted." The roots, leaves, leaf stalks and new stems of each tree were cut off and placed in separate vessels, the unexpanded leaves being included with the leaf stalks. These were dried in an oven at about 95° C. until there was no further appreciable change in weight, and the dry weights thus obtained. The mean values for the dry weights of roots, leaves and new stems, are given in the tables; those for the leaf stalks are not given separately, but are included in the values given in the last column, which represent the combined mean weights of leaves, leaf stalks and new stems. The fresh and dry weights of the "carcases," or old stems, were also obtained; the mean values for the dry weights are included in the tables.

TABLE II.

1930 *Investigation.*

Fresh Weights of the trees at the time of planting and of lifting, also the Dry Weights of the various organs at the time of lifting.

Harvest No.	Date when lifted.	Number of Trees.	Mean Total Fresh Weights.		Mean Dry Weights.				
			When planted.	When lifted.	Old Stem.	Roots.	Leaves.	New Stems.	Total* New Shoots.
0	1930 10 April	50	70.38 *2.284*	—	35.687	1.094 *.1179*	—	—	—
1	29 May	46	64.38 *2.239*	71.14 *2.395*	29.598	1.152 *.0911*	1.264	.153	1.672
2	1 July	48	60.62 *2.197*	83.90 *2.712*	30.265	2.094 *.1170*	3.907	1.091	5.467
3	5 Aug.	49	63.11 *2.470*	108.55 *3.261*	36.269	4.014 *.1729*	5.530	2.249	8.457
4	10 Sept.	42	66.97 *2.809*	138.35 *4.871*	42.066	7.339 *.3282*	7.578	4.297	12.712
5	22 Oct.	49	66.06 *2.498*	146.91 *6.303*	47.063	10.477 *.4963*	7.605	5.752	14.240
6	11 Dec.	50	64.15 *2.173*	128.78 *4.838*	46.921	12.242 *.5759*	Leaves fallen.	5.856	5.856

Harvest 0 represents the initial sample taken at the time when the remaining trees were planted.

* *Vide* Table I.

Many other records were taken on the trees, but the data from these will not be presented in full in this paper, though reference to some of them will be made in the discussion. These included counts of the number of leaves, and, in some cases, measurements of the leaf area. The lengths of all new shoots were recorded and the diameters of the old shoots. In most cases the fresh weights as well as the dry weights of the various organs were obtained. During the

winter months of 1929-30, the fleshy roots were separated from the older brown roots and their respective dry weights obtained; these, however, have been summed together in Table I. In the harvests taken during the summer of 1930 the dry weights of leaves and stems from leader shoots (i.e. shoots more than 5 cm. long) and those from the shorter shoots and spurs were determined separately. The values for these two types of shoot have, however, been summed in Table II.

The writer especially wishes to thank Miss I. D. Skinner for assistance in the taking of records at all the harvests, and Dr. R. C. Knight, who helped at the time of certain harvests; he also wishes to thank Mr. W. Bickel of Weihenstephan, Munich, Mr. H. K. Hewison of the Investigation Station, Kpeve, British Togoland, Mr. A. M. Mustafa of the North-West Province, India, and Mr. F. R. Tubbs of the Tea Research Station, Ceylon, all of whom rendered valuable assistance at various times when staying at this Station.

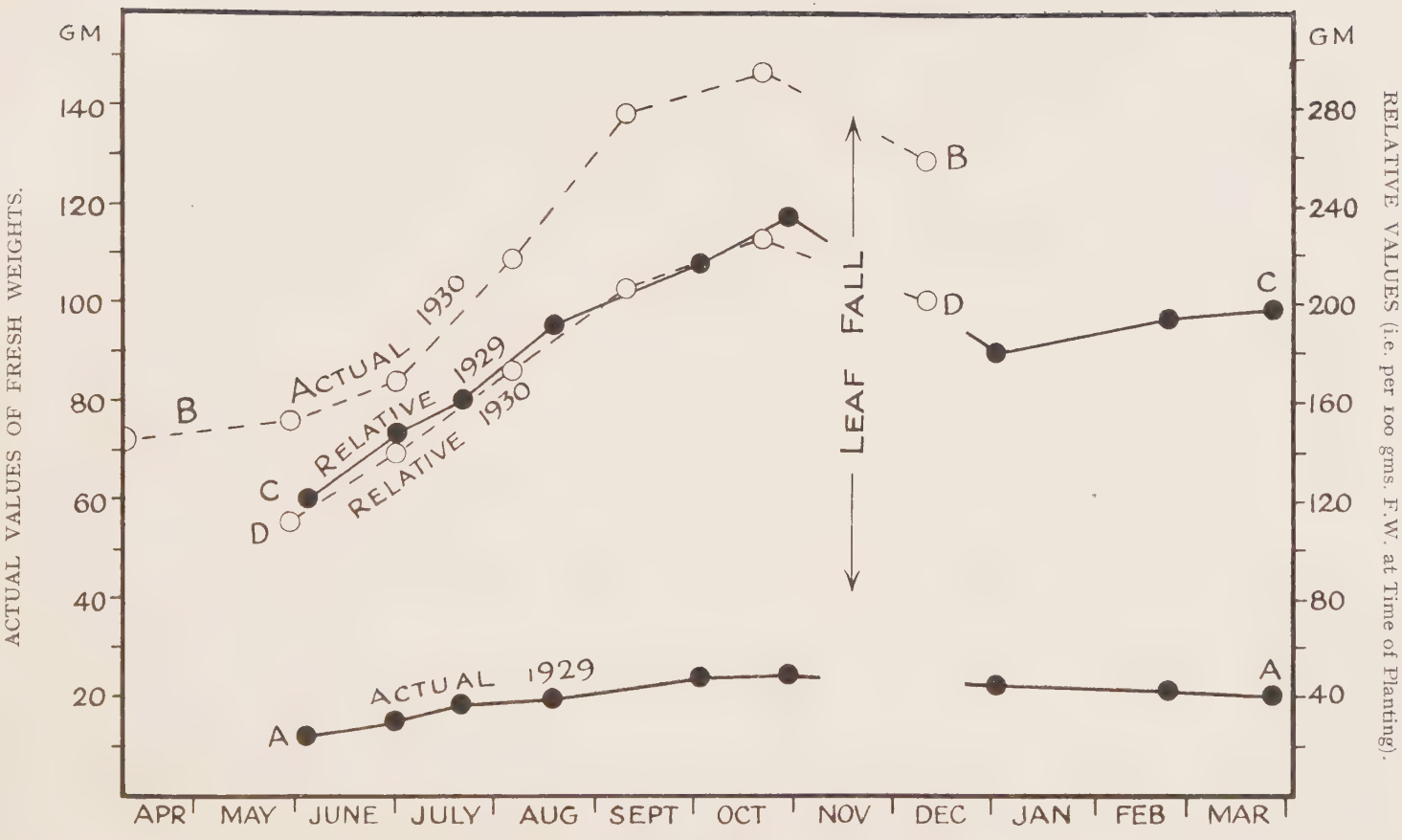
Discussion of Results.

Effect of Initial Size.

The mean fresh weights at the time of successive harvests are plotted on Graph 1. Curve A refers to the 1929 trees (given in column 5 of Table I), Curve B to the corresponding values for the 1930 trees. The two curves, plotted thus on the same scale, are widely apart, showing that the actual weights were very different. There seem three possible causes for the wide divergence between the two curves. First, the trees were of very different initial weights; the 1929 trees being only about one-sixth the weight of those used in 1930. Secondly, they received different treatments: the 1929 trees being planted with stems unpruned but the roots removed, the 1930 trees with their stems pruned but with the roots still on. Thirdly, they were grown in different years.

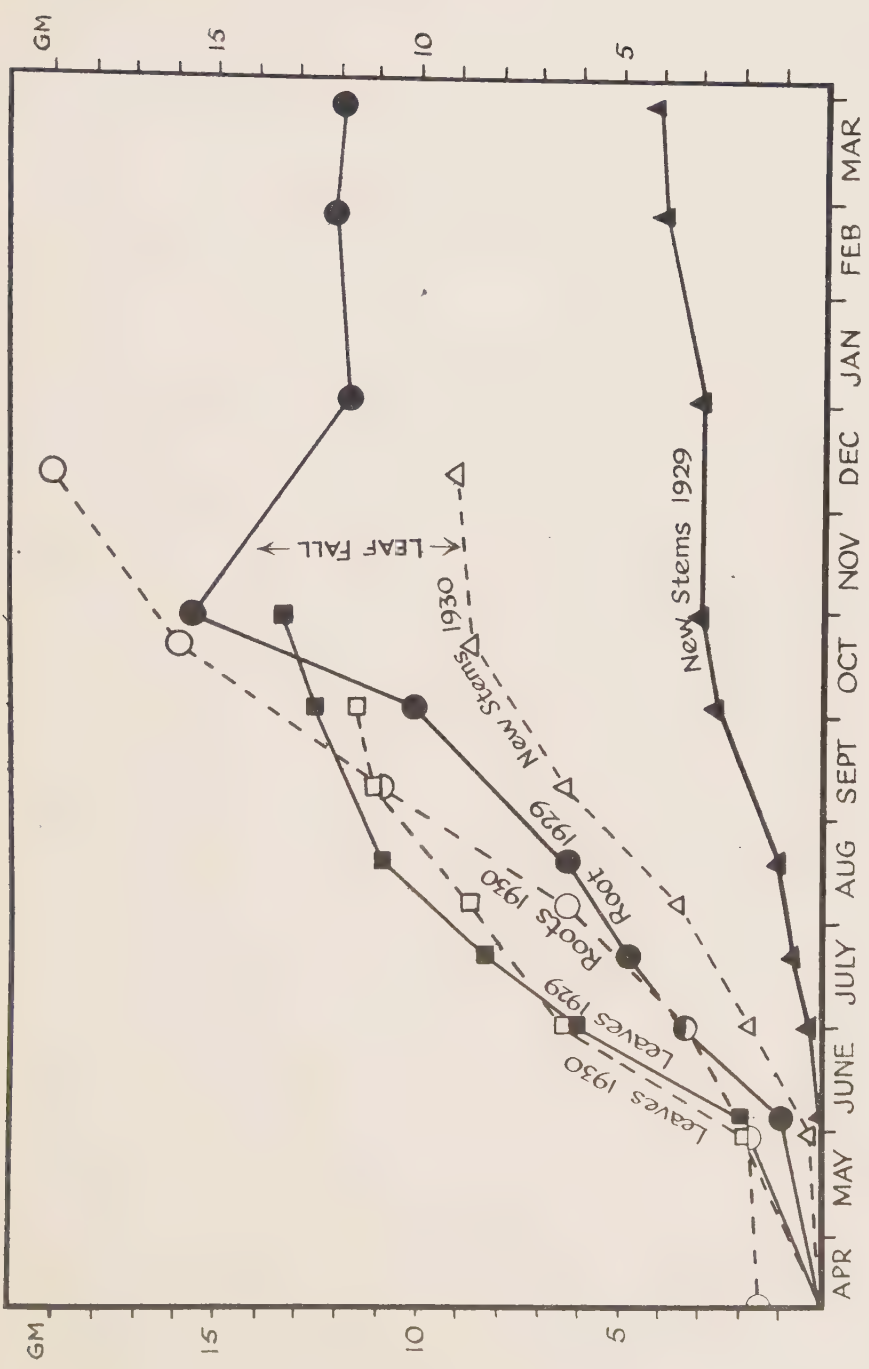
To determine to what extent the subsequent differences in weight can be accounted for by the initial differences at time of planting, the two sets of values have been reduced to the common basis of "grammes final fresh weight per 100 grammes initial fresh weight." In other words, each value in the fifth columns of Tables I and II has been multiplied by 100, and divided by the associated value in column 4. Curve C plots the resulting values for the 1929 trees, curve D, those for the 1930 trees; the two curves are now very close; through most of the season they practically coincide. Similar curves of actual total dry weights and of dry weight on the basis of initial fresh weight can be drawn, but they show the same features as those for fresh weights and are not given here.

The close correspondence of the two curves C and D shows that the *relative* rates of growth were much the same in the two seasons; both sets of trees took about as long to double in weight, and trees that were six times as heavy as others at the time of planting were still six times as heavy at the end of the



GRAPH 1.

Actual and Relative Fresh Weights at times of Successive Harvests.



Graph 2.

Dry Weights of Roots, Leaves, and New Stems per 100 gms. of total Fresh Weight at time of Planting.

maiden year. Thus the differences in initial size account for practically the whole of the divergence in the subsequent weights.

This demonstrates the desirability of using first grade material when planting out stocks for subsequent working; second grade material will not catch up with first grade by growing faster during the maiden year. It emphasizes, too, the necessity of using uniform material in all experimental work, and of knowing the exact initial weight of every tree.

It must not be forgotten, however, that these observations refer to the Maiden year and that it does not necessarily follow that they will apply to trees of greater age.

Distribution of Growth between the Various Organs.

Since the two curves for total dry weight coincide so closely when plotted on the common basis of initial fresh weight, it seems legitimate to express the dry weights of the constituent parts, old and new stem, roots and leaves on the same basis. The values for the roots, leaves and new stems, given in columns 7, 8 and 9, respectively of the tables, have accordingly been multiplied by 100, as before, and divided by the appropriate values in column 4. The values obtained thus for the 1929 and 1930 trees are plotted on Graph 2. The two curves for leaf weights correspond fairly well, so too do the two for root weights; the course of growth of these organs will be discussed more fully below. It is obvious, however, that the two curves for new stem are very widely divergent, indicating that the relative rates of growth of these organs were very different in the 1929 and 1930 trees. The new stems of the 1930 trees grew much faster than those of the 1929 trees. The curves of increase in weight of old stems are not given, so as not to overload the graph; but they can be worked out in the same way as the others and show that the faster rate of growth in the new stems of the 1930 trees was compensated for by a slower rate of growth in their older stems. An earlier investigation carried out by Dr. Knight has shown that pruning can bring about just this redistribution of growth, so that the pruning of the 1930 trees was the probable cause here. The effect of pruning is only an incidental problem in the present investigation, and a full description and discussion of the earlier investigation, which was designed especially to throw light on that problem, will shortly be published by Dr. Knight; the matter will therefore not be entered into further here.

Course of Leaf Growth.

The curves for the mean dry weights of leaves are of the usual S form, indicating that the rate of increase in weight was high early in the season, but gradually fell as summer and autumn advanced. As weight per unit surface usually increases with the age of the leaf, it is probable that much of the rise

in the values, in the latter part of the season, was due to thickening up of the leaves rather than to the formation of new leaf surface. The weights of leaves from leader shoots and short shoots were determined separately during most of the 1930 season ; their respective values are of some interest and are given in Table III.

TABLE III.

Dry Weights of Leaves from Leader Shoots and Short Shoots. 1930.

Harvest Date	1 29 May.	2 1 July.	3 5 Aug.	4 10 Sept.	5 22 Oct.
Leader	1.264	2.350	3.904	5.884	6.295
Short		1.557	1.626	1.694	1.310
Total	1.264	3.907	5.530	7.578	7.605

The weight of the leaves borne by leader shoots more than doubled between July 1st and September 10th and increased even after that date. The weight of the leaves of the short shoots, on the other hand, showed little increase after the beginning of July, and actually decreased after the beginning of September, presumably owing to the fall of some of the leaves. This difference in behaviour is in accordance with expectation.

Course of Root Development during the Maiden Year.

The data for the summer and autumn months of two seasons are available for comparison. The curve for 1929 (*vide* Graph 2) would seem to favour the view that there are two periods of rapid root growth, one in early summer and the other in autumn, but the curve for 1930 does not bear this out ; it is clearly of the S form, implying that growth steadily decreased as the season advanced. The difference was probably due to weather conditions. There was a very dry spell in August, 1929, which corresponds with the period of rather slow growth ; August, 1930, on the other hand, was a wet month. There seems to be no justification for calling either type of curve the " normal " one for root growth ; presumably the one will be usual in districts where August is usually dry, the other where that month is generally wet. In spite of the difference in the times of most rapid growth, the relative amounts of roots made before the end of October were about the same in the two seasons ; in each case the final dry weight of the roots was considerably greater than that of the leaves.

Only the data from a single winter (1929-30) is available as yet, though the investigation has been planned to include two further winters. The differences between the performances of the roots during the two summer periods show the necessity for great caution when interpreting data from a single season. Moreover, the winter 1929-30 was exceptionally wet and was followed by considerable

mortality amongst trees on clay in certain districts ; although there was no such mortality on the lighter loam of Malling, it is possible that the season may have caused abnormal root behaviour even here.

The rapid increase in root weight found in the summer months did not continue during this winter ; there was actually a considerable decrease in weight between the end of October and the beginning of spring. This does not necessarily mean that absolutely no new roots were formed, for most of the dry weight is made up of carbon, and, after leaf fall, the tree can get no new supplies of this element from the air ; all new root formation must therefore be at the expense of material stored in older organs. The increase in dry weight due to the formation of new roots will be compensated for by an equivalent loss in weight by these older organs through the removal of these materials. Some further weight will, moreover, be lost through the destruction of material in respiration, which will be particularly active where new growth is taking place.

The ninth and final harvest of the 1929 trees was taken towards the end of March. Bud-break was in progress and one of the seventy-three trees lifted had actually two or three small leaves expanded. Although the mean dry weights of the roots was found to have fallen since the previous harvest, there were numerous gleaming, white, new-looking roots on many of the trees. It is probable, therefore, that active root formation was in progress at that time.

Summary.

The course of growth during the maiden year, and its distribution between roots, leaves and stems, has been followed in the unworked apple stock Malling No. XIII during two seasons ; the sampling method was used.

The total weight (including leaves) became more than double between April and October. The increments during each period were approximately proportional to the weights at planting, whether the trees used were large or small, pruned or unpruned before planting.

The rate of increase in leaf weight decreased progressively during summer ; spur leaves ceased growth far earlier than the leaves of leaders.

The relative amounts of roots formed by rapid growth in summer and autumn were about the same in both seasons, but the times of fastest growth varied, apparently, with weather conditions. The dry weight of roots formed before November was greater than that of the leaves.

The roots decreased in dry weight during the winter 1929-30, but this may have been due to the exceptionally wet season.

Active new root formation was observed at the time of bud-break.

Addendum.

Since going to the press, a further—seventh—harvest of the 1930 trees has been taken, on February 19th, 1931. The mean values of the weights and their standard errors (given in italics) were as follows. Fresh weight of trees at time of planting 67.27 gm. (*2.301*), at time of lifting 135.85 gm. (*4.371*). Dry weight of old stem 47.145 gm. (*1.404*), of roots 12.231 gm. (*.4986*), of new stems 5.877 gm. The actual values of the dry weights are thus almost identical with those found at the sixth harvest, in December, 1930. The *relative* values, however, that is, the dry weights per 100 gm. original fresh weight, show a slight fall; for the original fresh weight of the trees used in this seventh harvest, 67.23 gm., is slightly greater than that of those used in the sixth harvest, 64.15 gm. These results confirm the conclusion, drawn from the data obtained during the previous winter, that the weight of roots and other organs does not increase during the winter months. It seems, however, that the considerable decrease in root weight, found that winter, was due, as suspected, to the exceptionally bad season.

Section III

Biochemistry

THE CHEMISTRY OF THE ROOTSTOCK-SCION EFFECT.

I. THE ELEMENTS ABSORBED FROM THE SOIL.

A Progress Report.

By W. A. ROACH.

The rootstock on which a tree is worked influences it with regard to its general habit and rate of growth, the age at which it begins to fruit, the season at which its fruit matures, the size and colour of its fruit, its susceptibility to certain diseases and many other ways; but the varietal characters, though to some extent masked, are preserved. Many of these mutual influences between stock and scion prove to be both well defined and reproducible, hence their underlying causes are being sought for by chemical methods.

The pomologist working along empirical lines has not only been able to turn some of these rootstock effects to practical advantage but, as a result of standardization of rootstocks, has also increased the degree of accuracy observable in experiments with fruit trees. Nevertheless he and the geneticist are both beginning to feel the need of some understanding of the real nature of these effects; for though certain generalizations may apply to the great majority, none is without its exceptions; and some of the exceptions are of the greatest theoretical and practical importance.

A chemical attack on the problem should proceed in three stages: first it must be determined how rootstocks differ from each other chemically and what chemical differences the rootstock and scion induce in each other; next, individual chemical characters must be found, if they exist, corresponding to individual horticultural characters; and lastly it must be ascertained for each pair of such characters whether the association is merely accidental or whether the one is really a consequence of the other. This may be tested by inducing the chemical change artificially in a suitable tree and watching for the appearance of the particular horticultural character. Take for example a simple type of possibility: perhaps it may be found after a number of chemical differences between types of rootstocks have been established, that resistance to a particular disease is always associated with the presence of one chemical element. This element would then be introduced in some way into trees normally lacking it to see whether, as a result of its introduction, they would become resistant to

the disease. This example will serve the present purpose, though not all associations of characters are likely to be of such a simple nature.

If the problem is attacked along these lines there is some hope that in the same way as the rootstock effect has been used practically to induce such valuable characters as early fruiting, good flavour, bright colour, etc., so the results may provide the key to the possibility of inducing such characters by introducing known chemical compounds through the soil by manurial means or even by injection directly into the tree.

Though the solution of such a complex problem can hardly be a simple one it is best to investigate the simplest possibilities first. When Bramley's Seedling is worked on rootstock No. XII a large, sturdy orchard tree is obtained which may not bear for ten to fifteen years, but when this variety is worked on rootstock No. IX a small tree of a characteristic drooping habit is produced which may begin bearing in its second year and may be bearing heavily in its fifth year, the fruit for the first fifteen years, at least, being larger, more highly coloured, and ready for market a fortnight earlier than that on No. XII. There are many other differences between the two trees. They are of the same variety but are on different rootstocks, and the differences in their behaviour may arise either because the stocks select different substances from the soil, or the same substances in different proportions, or because they make different use of them in their life processes.

All the chemical elements absorbed from the soil by the roots, with the exception of nitrogen and sulphur, remain in the ash after the plant is burnt, and the present communication records the results of a preliminary examination of the ashes of various parts of such apple trees to determine whether there are any differences in respect of their absorption from the soil and their distribution throughout the tree.

The material used consisted of a collection of two-year budded Lane's Prince Albert trees worked on rootstocks Nos. IX and XII. Each tree was divided into : (1) roots, (2) rootstock stem, (3) one-year old stem from the bud union to where the stem had been cut back the previous winter, and (4) the three or four current year's shoots arising just below the cut. Each of these portions after cleaning was separated into wood and bark. The reduction to ash was carried out in a glazed silica basin shielded from dust, and heated over a Bunsen burner, the minimum temperature at which glowing took place being aimed at.

The ashes were examined spectrographically in the carbon arc by Professor H. Dingle of the Imperial College and the following notes are extracted from his reports. The twenty-one elements occurring in the ashes were : potassium, calcium, magnesium, phosphorus, sodium, iron, aluminium, manganese, barium, strontium, lithium, copper, lead, titanium, vanadium, silicon, nickel,

chromium, tin, molybdenum and silver. They are arranged roughly in order of abundance.

All except the first three or four occur in minute amount only. Iron makes up about one-fivehundredth part of the ash ; yet it is just as essential for the plant's growth as potassium, which makes up one-quarter, or even one-half, of the ash. The proportion in which an element occurs in the ash, therefore, is no indication of its importance to the plant, and an element cannot be ignored or regarded as unimportant simply because it occurs only in minute amount. Lithium serves as an example of an element which, though apparently not essential for growth, may yet exert a profound influence on the health of the plant. Thus it is known that wheat is rendered resistant to mildew if lithium (as phosphate, nitrate or carbonate) is present in the culture solution in which it is grown to the extent of one part of lithium in 500,000 parts of solution (1).

Except as specified later, the twenty-one elements occurred in all parts of the tree, though there appeared to be differences in the amount present in one part and another. Thus the amount of aluminium appeared to become less the further from the root the samples were taken. Lead was restricted to the wood of the root (the outermost layer of the bark of over-ground parts also contained lead, but this was derived almost certainly from lead arsenate sprays with which the trees had been treated to keep down insect attack). Molybdenum occurred in the wood of the roots and the rootstocks of the six trees on No. IX, but was absent from all other parts of trees on this rootstock. It was also absent from all parts of the ten trees on No. XII.

The trees grew in two adjoining parallel lines, and there was no indication in the results themselves that the differences were due to variation in the composition of the soil. As far as could be judged from appearance the soil was uniform at least to the depth reached by the roots. Spectrographic examination of the soil by the same method as that applied to the ash failed to detect molybdenum. This suggests that this element is selectively absorbed by No. IX rootstock and that sufficient of it accumulates in the tree to be detected in the wood, although the concentration of molybdenum in the soil itself is too low for its detection by the methods used.

No finality is claimed for any of these results, but they do suggest that through its roots a rootstock may exert selective action in absorbing elements from the soil, and that one rootstock may differ from another in the way it exerts this selective action. The bearing of this on the rootstock-scion problem is obvious ; the results suggest that as the sap travels up the plant some elements are withdrawn from it more rapidly than others, with consequent modification of composition of the solution which eventually reaches the scion.

These indications justify a detailed examination of the problem. For this purpose quantitative analyses of the ashes are highly desirable. Some progress

has already been made in adapting a physico-chemical method which should be applicable to the majority of the elements, and the recent acquisition of spectrographic apparatus makes possible the development of methods applicable to the remainder of these elements.

It is a pleasure to acknowledge the writer's indebtedness to Professor H. Dingle for the spectroscopic work referred to above and for much helpful advice, also to the governing body of the Imperial College of Science and Technology for allowing their instruments to be used for the purpose of this investigation.

Summary.

1. The spectrographic examination of the ashes of various parts of two-year budded Lane's Prince Albert apple trees worked on rootstocks Nos. IX and XII has revealed the presence of the following elements: potassium, calcium, magnesium, sodium, phosphorus, iron, aluminium, manganese, barium, strontium, lithium, copper, lead, titanium, vanadium, silicon, nickel, chromium, tin, molybdenum, silver.

2. Most of these elements were distributed throughout the whole plant.

3. Lead was restricted to the roots.

4. Molybdenum occurred only in the roots and rootstock of trees on No. IX up to the bud union and was absent from all parts of the scion.

5. Molybdenum was absent from all parts of trees on stock No. XII.

Reference.

(1) *Spinks, G. T.* Factors affecting susceptibility to disease in plants. Part I. Journ. Agric. Sci., 1912-13, **5.** 231-47.

THE CHEMISTRY OF THE ROOTSTOCK-SCION EFFECT.

II. METHODS FOR TESTING THE EFFECTS OF SUBSTANCES IN SOLUTION ON FRUIT TREES.

A Progress Report.

By W. A. ROACH.

It is well known that an apple tree, in common with other plants, absorbs from the soil compounds which contain certain chemical elements that are essential for its growth. These include potassium, calcium, phosphorus and nitrogen, which are the chief elementary constituents of artificial manures. Magnesium also is an essential element but, because of its widespread occurrence, it is rarely necessary to add it artificially. Iron is of equal importance to the plant, as it is essential in minute amount for the formation of the green colouring matter. Usually there is no shortage of this element, but under certain conditions the plant cannot obtain enough iron, and it then becomes chlorotic, a condition comparable with anæmia in human beings.

There is increasing evidence that manganese must be added to the list of essential elements, though the exact part which it plays in the plant's economy is not yet known. Copper, if not an essential element, has been shown to be highly advantageous under certain conditions when applied to various crops at the rate of 30 lbs. copper sulphate per acre (1). Lithium, also in minute amount, exerts a profound influence on the power of resistance to parasitic attack of at least one kind of plant (4).

Practically nothing is known of the part played in the life of the plant by the remainder of the twenty-one elements present in apple tree ash, viz. : sodium, aluminium, barium, strontium, lead, titanium, vanadium, silicon, nickel, chromium, tin, molybdenum and silver. Three of these elements—aluminium, lead and molybdenum—were shown by the preliminary examination to have interesting distributions in the apple tree. As work proceeds additions are likely to be made to this list, and the determination of the functions of such elements becomes necessary.

The most obvious method of carrying out such tests is to apply a compound containing the element to the soil, as is done with manures ; but most soils already contain all the elements to be tested ; hence this method is at the outset

limited to those elements for which suitable soils can be obtained. Even if a soil sufficiently free from the element in question is available, there are still difficulties. Few substances remain unchanged for long on being mixed with soil ; some are changed into insoluble compounds and may not be available to the plant ; furthermore they may even bring into solution in their stead an equivalent amount of another substance, in which case the plant shows response to the liberated substance, not the one added.

These disadvantages can be almost entirely eliminated by growing the trees in pure sand instead of soil, but the final purification of even the purest quartz sand obtainable is a troublesome and expensive process. In addition the choice of vessels sufficiently free from the elements in question and sufficiently insoluble themselves adds a new difficulty, whilst their cost for the present purpose would be prohibitive. Chemicals are not obtainable in a sufficient degree of purity for making up nutrient solutions when they have to be free from such minute traces as those in which some of the elements occur in the ash ; and the necessary careful analysis and purification of them would take more time than could be given to this part of the problem at present. Hence sand cultures are quite unsuitable for the present purpose.

Growing the trees in water to which the necessary substances are added dispenses with the use of sand and the attendant difficulties, but suffers from the other disadvantages of the sand culture method and, in addition, aëration of the roots becomes a serious difficulty.

The water and sand culture methods appear to be the only ones capable of throwing light on the functions of those elements which occur in minute amounts and are of uniform distribution, but for those elements which are less abundant in one rootstock or tree than another (i.e., the ones in which we are mainly interested) the possibility exists of introducing a chemical solution directly into the tree in which the particular element being studied is normally less abundant. By such means the effect of artificially raising the concentration of an element in a tree in which it is normally low to that of trees in which it is normally relatively high can be observed. The main necessity, therefore, is a method of introducing a solution directly into the tree without the intervention of soil or the use of sand or water cultures.

Injection Method. In the same way that human beings are injected with a liquid by means of a hypodermic syringe trees can also be injected ; but because of the hardness of the wood it is convenient to drill a hole and fix into it a tube connected with a reservoir containing the liquid. This is raised some feet above the injection hole so that the liquid in the reservoir enters the tree under pressure. Using this method Lipman and Gordon (3) have succeeded in introducing into a ten year old pear tree sixty-three litres (14 gal.) of liquid in twelve hours. The chief drawback to this method is that the deep wound inflicted heals only

superficially and slowly ; hence a way of entry for disease is kept open, but this need not be serious.

Leaf Pull Method. Dr. R. C. Knight has been making use of the fact that the upward pull exerted by the leaves on the sap is greater than the push of the root pressure ; a small branch is cut off under water near the base of the tree and its end is kept under the surface of the liquid which is drawn up into the tree.

Before adopting this method the writer wished to know how the absorbed liquid became distributed in the tree, for it is necessary to know with certainty exactly where the liquid will penetrate before accurate observations can be made of the effect of the substance introduced. Solutions of substances containing three different elements (lithium, magnesium and molybdenum), chosen as suitable representatives of the types of substances to be tested, were made up of such a strength (1 per cent.) that they would injure the tree and so would leave their trail marked by damaged leaves and bark.

A small branch near the base of a two year old budded cordon apple tree was cut off in summer about one inch from the main stem, the cut being kept wet with a jet of water. A glass tube was then attached thereto with a short piece of rubber tubing, and the solution to be tested was poured into the tube. As much as 30 cc. was absorbed in the course of three days, whilst damage showed itself within a week.

Only a few branches of the trees that absorbed the magnesium chloride and potassium molybdate solutions showed damage, all of them being above the cut one. They were distributed at irregular intervals in a more or less vertical line up the main stem. The terminal current year's shoot usually had at least its basal leaves damaged, and often all its leaves. There was a tendency therefore for the solution to ascend the stem in the vertical direction and not to spread around or across the main stem. It cannot be predicted, however, whether a particular branch will be permeated by the liquid or not, hence this method is not suitable for the present purpose, for it would not be possible to tell which branches contained the substance and which were free from it if the solution were dilute enough to cause no visible damage.

Even when three consecutive branches (three making a complete circle of the apple tree stem) were treated, the distribution was not satisfactory.

The results with lithium sulphate were similar except that there was some movement downwards and, to a smaller extent, around the stem ; but the main movement was still vertical.

Method for introducing solutions into cordon trees. When the top two to three inches of the terminal shoot were cut off and the tube was attached to the cut end the rate of absorption was greater than in the experiments just described. In three days as many as 90 cc. were absorbed by a tree four feet high. After

a week every branch of the top half of the tree was damaged, the severity of the damage decreasing uniformly down the stem, the top branches being killed and those about the centre of the tree being only slightly damaged.

A series of trees was treated in this way with decreasing concentrations of potassium molybdate, four trees being used for each concentration. The severity of the damage decreased with decreasing concentration, but the distribution was the same for all toxic concentrations. It cannot be assumed that at lower harmless concentrations the substance will have the same distribution, but similar experiments carried out by other workers with harmless dyes also point to this conclusion; the question can best be settled by chemical analyses of treated trees. It seems highly probable, however, that the method will be satisfactory for testing the effect of a solution on the top part of a cordon tree. Possibly if pressure were applied to the liquid it would permeate the whole tree. This possibility will be tested next season.

Method for introducing solutions into lifted rootstocks and similar material. Seeing that even a well-rooted stock when still on the parent stool probably derives the main portion of its water from the stool the cut by which it is severed from the stool should be a good absorbing surface. To test this idea, stocks were cut from the stools in the usual way, plunged immediately into a bucket of water and removed in this to the laboratory. Each stock in turn was held with its base under water and, after suitable trimming of the roots, enough was cut from the base to give a " clean " surface. Whilst still under water a glass tube was fixed to this cut end with a short length of rubber tubing ; the water in the tube was then poured out and the solution to be used quickly poured in. The tube was fixed by a rubber band to a horizontal wooden batten, with the leafy shoot hanging vertically downwards. With suitable preparation beforehand, one or two hundred stocks could be done easily in a day.

Using one per cent. solutions of ammonium chloride, ammonium nitrate, and potassium nitrate, every leaf on the stock became slightly damaged, usually at the end of twenty-four hours and almost always at the end of forty-eight hours. There was little difference in the severity of the damage to the top and bottom of the stock ; this method, therefore, seems to give a nearly uniform distribution of the solution throughout the whole above-ground part of the stock. If necessary, the roots could be protected to prevent drying up. After removing the tubes the cut ends were dipped in molten paraffin wax to prevent the solution diffusing out, and the stocks were bedded in the usual way.

This method was found suitable also for stocks which had been bedded for a year, except that with such material it was necessary to cut off a little more of the base than for stocks removed directly from the stools.

This method has been used in preliminary experiments with lithium nitrate, sodium chloride, potassium chloride, magnesium chloride, copper chloride,

silver nitrate, ammonium chloride, ammonium nitrate, potassium nitrate and potassium dihydrogen phosphate, about 600 stocks having been used.

It may be added that absorption through a side branch of such lifted material led to more perfect permeation of the plant than when normally-growing trees were so treated.

Discussion.

Auchter (2) concludes that "the mineral nutrients absorbed by the roots on one side of a plant are in a large measure translocated to and used by the trunk, limbs and leaves directly above them. There is apparently very little cross-transfer of such nutrients in the plant . . ." The material used for the work described in this note was chosen as far as possible so that the minimum cross-transfer was necessary to give uniform distribution of the introduced substance throughout the plant; the results were in substantial agreement with Auchter's conclusion but there were indications of some degree of cross-transfer. In experiments which are contemplated on larger trees an attempt will be made to see how far cross-transference can be brought about by the application of obvious mechanical principles.

Summary.

1. A résumé is given of a number of methods for inducing apple trees to take up solutions through cut surfaces.

2. By using toxic concentrations of the substances, their "trails" were marked by damaged tissues.

3. When the cut end of a small side branch near the base of a tree was kept under the surface of a solution the solution was absorbed, but its distribution in the tree was irregular.

4. Absorption through the cut end of the terminal shoots of a cordon apple tree resulted in the permeation of every leaf on the top half of the tree; the damage caused by the more concentrated solutions diminished from the top downwards.

5. Stocks taken straight from the stool readily absorbed solutions when hung inverted with their cut ends connected to tubes containing the solution. When the solution was concentrated every leaf was damaged, the terminal leaves being only slightly more damaged than the basal ones.

6. Bedded rootstocks could be treated in a similar manner.

7. Absorption through a side branch of a rootstock led to more general distribution throughout the plant when it was lifted than when it was growing normally.

8. Lithium sulphate permeated more freely than either potassium molybdate or magnesium chloride.

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PRELIMINARY EXPERIMENTS ON THE PHYSIOLOGY OF THE RESISTANCE OF CERTAIN ROOTSTOCKS TO ATTACK BY WOOLLY APHIS.

By W. A. ROACH and A. M. MASSEE.

Introduction.

Woolly Aphis is a serious pest of apple trees in various parts of the world, so serious that in certain countries it has been found necessary to prohibit the use of all susceptible rootstocks, however desirable they may be in other respects. The overseas parts of the British Empire chiefly concerned are New Zealand, Australia, India, South Africa and Canada. France and the United States of America suffer losses in the same degree. In our own country serious damage is caused in the Western Counties ; elsewhere the incidence of the pest is more localized, though the attacks are often just as severe.

In New Zealand and elsewhere the pest is being controlled biologically by means of the parasite *Aphelinus mali* (Hald.) but in many localities the results are disappointing, and the alternative of growing trees on a resistant rootstock, Northern Spy, remains the only effective measure. In pomological experiments carried out at the East Malling Research Station, Northern Spy, when used as a rootstock for Grenadier, has, in comparison with other rootstocks been " classed as semi-dwarfing of the Doucin (Malling No. II) group but comparing unfavourably with it in early cropping " (4). In addition, Grenadier grafted on it was particularly prone to attack by Mildew (*Sphærotheca leucotricha*), hence there is little to recommend it as a rootstock for this district, apart from its immunity from Woolly Aphis attack. Even in countries where aphis attack is serious and where, in consequence, Northern Spy is extensively used as a rootstock because of its immunity, doubts as to its all round suitability for commercial orchard use are increasing. For this reason the East Malling Research Station, in co-operation with the John Innes Horticultural Institution, has been attempting for some years to combine in one rootstock, by breeding, immunity from Woolly Aphis attack with the virtues of some of the best types of rootstock grown in this country.

In the course of this work the raising of thousands of seedlings for artificial inoculation with the insect will be entailed. Not all susceptible seedlings become infected the first year ; in fact, at least five years must elapse before a newly raised seedling can be pronounced immune under local conditions.

Furthermore, its resistance must be tested under the special conditions which prevail where it is to be grown, say in some distant part of the Empire. Even after a rootstock has been proved to be immune a further period of at least ten years is required before its all round value as a rootstock can be assessed.

The investigation now to be described is an attempt to elucidate to some extent the cause of this immunity with a view (1) to devising some more rapid method of testing susceptibility than that of actual inoculation with the insect, and (2) to give what help is possible to the geneticist in defining the principles of breeding for immunity from this pest.

Immunity Probably Physiological.

Attempts that have been made to break down the immunity of Northern Spy by mechanical means have been uniformly unsuccessful (5), hence although no final conclusion can yet be drawn, it seems likely that the immunity is not of a mechanical, but rather of a physiological, nature.

Two main types of possible physiological causes of immunity and susceptibility present themselves :

(a) The immune rootstocks may contain a substance or substances definitely inimical to the nutrition and growth of the insect.

(b) The immune rootstocks may lack some substance or substances essential for the normal development of the insect.

A preliminary attempt has been made to extract any such substances from the trees, three methods for testing the resulting extracts having been tried. In the first two methods the effects of the extracts on the insects have been tested

(1) by allowing trees inoculated with the insects to absorb the extracts, and

(2) by introducing the extracts into artificial cultural media on which the insects were fed.

In the third method by chemically comparing the extracts with each other, an attempt was made to detect some substance the presence of which was invariably accompanied by either (a) immunity or (b) susceptibility.

Method of Extraction.

In this preliminary work the simplest method of extraction was employed, more refined methods being avoided until their necessity or desirability was indicated.

As it seems unlikely that the insect is able to pierce the whole depth of the bark with its mouth parts and reach the wood (6), the bark alone was used in the first instance. The finely divided bark was dropped into about twice its weight of boiling water, digested on a steam bath for a few hours, and filtered.

JUICE ABSORPTION EXPERIMENTS ON TREES INOCULATED WITH WOOLLY APHIS.

For these experiments small trees of Kentish Codlin (susceptible) and Northern Spy (immune) that had been growing in 10 inch pots plunged in the soil in the open, were used. They were taken into the greenhouse, where the highest leader on the main stem was cut back into the previous year's wood, the tree being so placed that the cut could be made under water. While still in this position a glass tube was fixed to the cut shoot by means of a short piece of rubber tubing. With the tree returned to its normal position the water in the tube was removed and the filtered extract introduced as rapidly as possible. For maximum rate of absorption of the extract it was not found necessary to keep the moisture in the soil much below normal; in fact allowing the pot to reach the "chink" stage had to be avoided as this led to wilting and consequent decrease in rate of absorption.

Absorption of undiluted extract was followed in a few days by browning of the leaves, or even defoliation, of the branches nearest to the cut. This damage was used as an index of the areas penetrated by the extract. There was definite, though less severe, damage with an extract which had been diluted with twice its volume of water.

These and other experiments showed that the absorption of a sufficient volume of liquid resulted in the complete permeation of at least the branch nearest to the cut. All inoculation experiments were confined to these branches.

Little or no damage followed the absorption of extract ten times diluted, but it seems probable that its distribution would be similar to that of the extracts of which the course could be traced.

In these experiments five Northern Spy (immune) trees absorbed Allington Pippin (susceptible) extract, one with the extract undiluted, one with the extract diluted with twice its volume of water and three with the ten times diluted extract. These trees were repeatedly inoculated with Woolly Aphides by methods used successfully in the routine testing of seedlings (5); the aphides behaved in the same way as on untreated Northern Spy trees. In a corresponding series of Kentish Codlin (susceptible) trees absorbing Northern Spy (immune) extract every tree was heavily infected. None of these ten preliminary experiments, therefore, yielded evidence of any alteration in the relation between a tree and the insect, resulting from the absorption by the tree of an extract from a foreign tree. If immunity or susceptibility is conferred by a definite substance we must conclude either that the substance (1) was not extracted by the method employed, or (2) was destroyed in the extraction process, or (3) was modified in passing through the tissues of the tree before reaching the feeding insects, or (4) did not reach the insects but was held by the woody or other tissues through which it had to pass.

Artificial Feeding of Woolly Aphides.

The aim of this line of work is to decide whether Northern Spy owes its immunity to the presence of a substance harmful or repugnant to the aphis or to the absence of a substance necessary to the life of the insect and contained in the susceptible trees. If two artificial nutrient media could be made up similar in all respects except that the one medium contained a chemical fraction of the bark of a susceptible tree and the other the corresponding fraction of that from an immune tree, such that Woolly Aphides would thrive on the one and not on the other, it would then only be necessary to mix the two media and observe the effect on the insects in order to decide between these two alternatives. If the insects thrived on the mixed food it would indicate that there was no harmful substance in the immune tree, and that probably its immunity was due to the absence of a substance necessary for the life of the insect ; so that should the substance be added (in the susceptible part of the mixed media) there would be nothing to prevent the aphides thriving. If, on the other hand, the aphides did not thrive on the mixed food the presence of some harmful substance in the immune tree would be indicated. In either case the next step would be to separate by chemical or other means, the active extract (i.e., the one containing the immunity- or susceptibility-inducing substance) into further fractions, and to test which of the resulting fractions remained active, repeating the process on this fraction, and so on, until finally there remained a pure chemical substance which tests on insects suggested was responsible for immunity (or susceptibility). The testing of seedlings might then resolve itself into determining by chemical means the presence or absence of the substance in each seedling. In the foregoing the word "substance" has been used for simplicity, but immunity or susceptibility might equally well be due to a group of substances.

The first step along this line of work, therefore, is to build up artificial media, on which the insects can live healthily, with products of susceptible trees. Of the various methods tried only the two most hopeful ones will be described. In the first the medium was solid, and in the second it was liquid.

1. *Culture of Woolly Aphis on Solid Media.*

The food medium consisted of bark extract, to which was added 6 per cent. of its weight of agar. This was sterilized in the autoclave and poured into Petri dishes, precautions being observed to avoid microbial contamination. A disc of sterile blotting paper was placed in the lid of the dishes to absorb condensed moisture. The aphides (three was found a convenient number for a dish 6 cm. in diameter) were placed on the medium. If the dishes were kept upside down, with the aphides living and feeding in an inverted position, there was less bacterial and fungal contamination, but there was a slight tendency for

the aphides to fall off the medium, and some of them could not find their way up again.

By placing the inverted dish under the microscope the aphides could be observed through the transparent medium without disturbing them. They were frequently observed with their mouth parts buried deep in the medium, apparently feeding, though bright light or jarring caused them to withdraw their mouth parts.

The high concentration of agar (6 per cent.) was found necessary to prevent the legs of the aphides from penetrating the medium. When this happened the aphis came to a standstill and soon became enveloped in fungal mycelium and died.

Fungi at first were found a serious difficulty, since the whole plate became covered with mycelium well within a week. The growth of fungi was discouraged somewhat by the addition of 0.1 per cent. of erythrosin to the medium.* As soon as fungal growths could be detected under the binocular microscope the insects were transferred to fresh dishes. By adding erythrosin and transferring the insects to fresh sterile dishes every two or three days fungal trouble was reduced to a minimum. The nature of the fungal organisms is dealt with later (pp. 118 and 119).

Reference need be made only to the results of the last and most successful experiment. In this five media were used of the following compositions :

Medium	III	6 gm. agar	+100 cc. water.
,,	X	ditto	+100 cc. Allington Pippin extract.
,,	XI	ditto	+100 cc. Northern Spy extract.
,,	XII	ditto	+100 cc. Allington Pippin extract neutralized with ammonia.
,,	XIII	ditto	+100 cc. Northern Spy extract neutralized with ammonia.

The main results are illustrated in Fig. 1. At the top is shown the number of adult Woolly Aphides surviving on any particular day. It will be seen that the results for all five agar media are so close that it would not be safe to say that one medium was better than another. The insects on these media survived about twice as long as the controls which were placed in empty Petri dishes with no food. (Though the blotting paper in the control dishes was moistened it is possible that the atmosphere in these dishes was not sufficiently moist.) Thus the starved insects became halved in numbers (i.e., to nine) in five days (to the nearest day), and those on media III, X, XI, XII and XIII were reduced to

* This fact was discovered accidentally in an attempt to ascertain whether the aphides were feeding by giving them a coloured food, and afterwards observing the presence of the colouring matter in the insects' bodies.(3). These experiments did not give completely conclusive results because at one stage of its life-cycle the Woolly Aphis is naturally of a reddish colour.

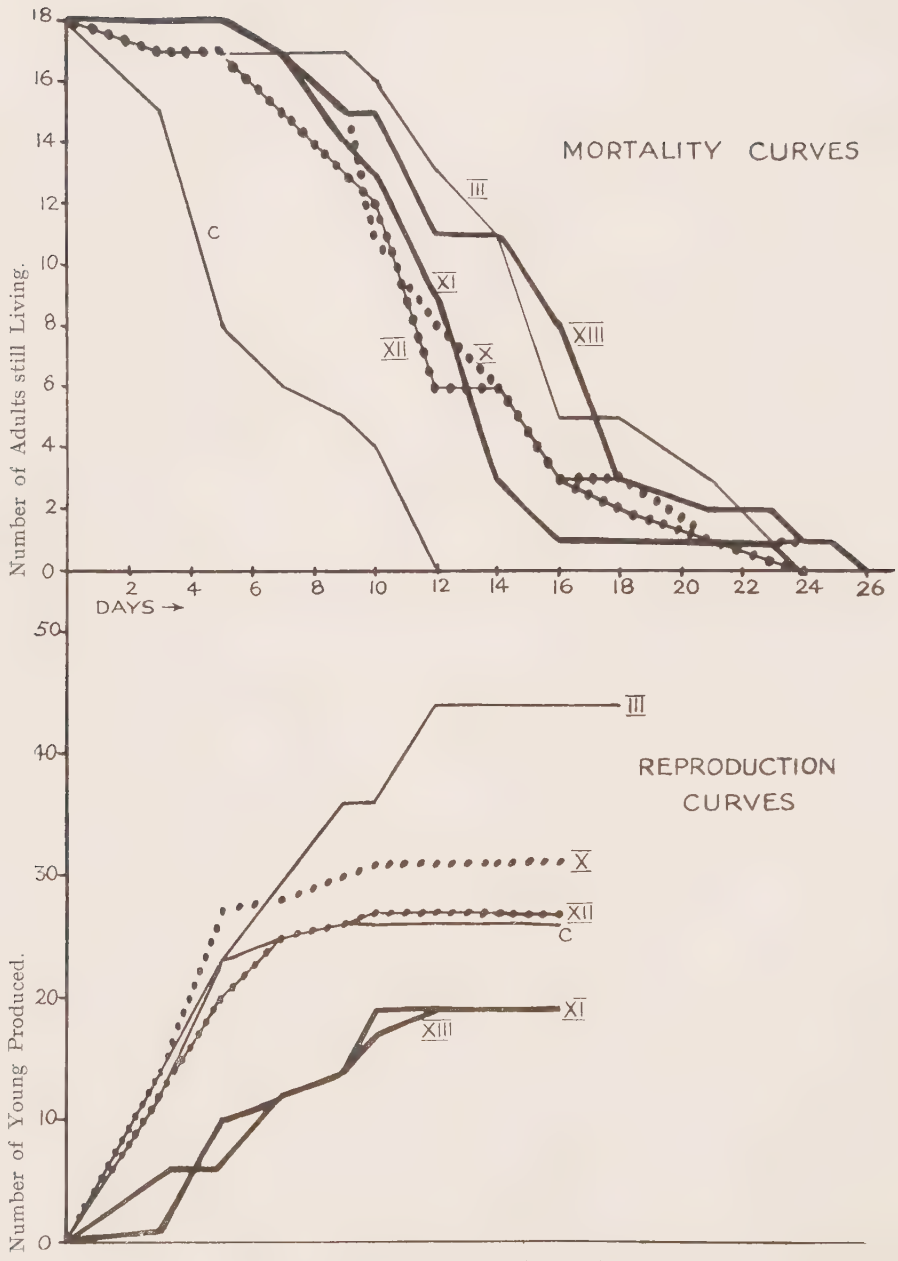

FIG. 1. Curves showing (top) mortality and (bottom) reproduction rates of Woolly Aphides cultivated on agar media.

C Empty Dishes.
III 6% Agar.
X +Allington Pippin Extract.
XI +Northern Spy Extract.
XII +Allington Pippin Extract Neutralized with Ammonia.
XIII +Northern Spy Extract Neutralized with Ammonia.

nine in fifteen, eleven, twelve, eleven, fifteen days respectively. At the bottom is shown the total number of young produced. It will be noticed that the agar alone gave the highest reproduction, reaching a total of forty-four; the two Allington Pippin media and the control media were about equal, all falling far short of the agar medium, the figures being thirty-one, twenty-seven and twenty-six respectively; and the lowest figures of all were given by the two Northern Spy media, the total figures for each being nineteen.

The fact that the young produced on the Northern Spy media XI and XIII were only slightly more than half those produced on the Allington Pippin and plain media X, XII and III is suggestive; but, it would be unsafe at this stage to attach much significance to this fact.

2. *Culture of Woolly Aphis on Liquid Media.*

In feeding Woolly Aphides on liquid media it is convenient to separate them from the liquid by means of a thin membrane (1) (2). The insects puncture the membrane and are then able to reach the liquid. In a number of experiments a variety of membranes and types of apparatus were tried. The form of apparatus found most satisfactory is shown in Fig. 2.

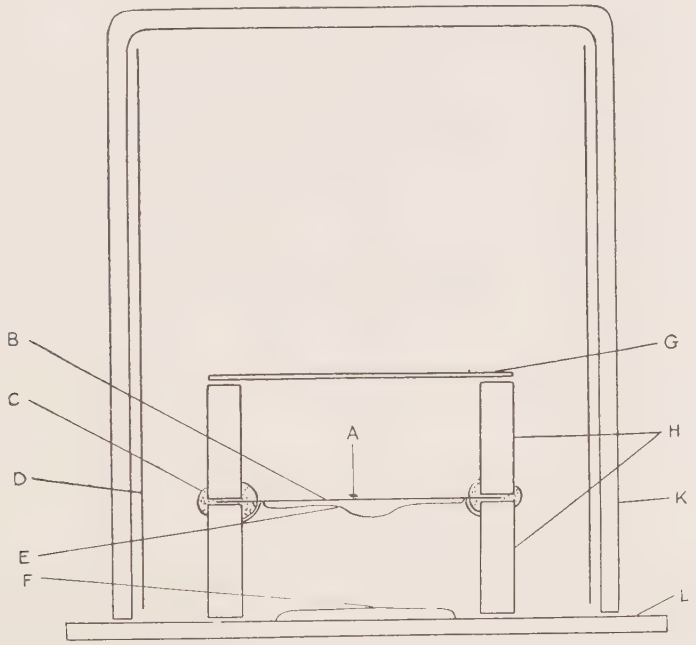

FIG. 2.—Apparatus for feeding Woolly Aphides on Liquid media. (×2).

A Woolly Aphis.
B Membrane.
C Paraffin wax.
D Wet blotting paper.
E Drop of medium.
F Water.
G Microscope cover slip.
H Glass rings.
K Glass tube.
L Glass slip.

One rim of a warmed glass ring was moistened with paraffin wax, which had previously been melted to form a liquid film covering a sheet of glass, and then held down on the extended membrane till the wax set, when a second ring was cemented on the reverse side of the membrane. The drops of water below the hanging drop of medium and the wet blotting paper were to prevent the medium drying.

As to the membrane used, up to the present the outer skin of current year's apple shoots has been employed. A susceptible variety of apple with few lenticels was chosen. A piece of bark rather larger than required to cover the ring was removed and placed, inner surface uppermost, on a glass sheet illuminated from below. The inner layers of bark tissue were removed with a knife and forceps, care being exercised in removing the final chlorophyll layer not to damage the remaining outer skin.*

Even with this somewhat opaque membrane the mouth parts of the aphides could often be seen protruding well into the culture medium. Such observations were readily made by removing the cap and placing the apparatus on the stage of the binocular microscope.

Fungi Associated with Woolly Aphis.†

Reference was made (p. 115) to the fact that numbers of fungi developed on media on which Woolly Aphides had been feeding. As might be expected many different fungi were represented, and in general there was no great similarity between one Petri dish and another; but dark fungal growths and pus-like yeast colonies occurred constantly in larger numbers than any others. Further, a few dishes showed a line of these colonies and growths ending with a dead aphis, suggesting a close association between them and the aphis (see Plate I). Though absolutely convincing evidence has not yet been obtained, it seems probable that the yeast colonies marked the sites of punctures by the mouth parts of the insects. The same may also be true of the fungal growths but the evidence is not so strong in this case. The colonies and growths were sometimes simple, consisting of yeasts or of filamentous fungi and sometimes a mixture of the two, but the dishes were rarely contaminated by other micro-organisms.

The association of symbiotic yeast-like organisms with aphides, and of entomophagous fungi with various insects is well known (7). As a first step in further testing the closeness of the association between the aphis and the yeast and filamentous fungi, Woolly Aphides were obtained, with the help of friends, from six localities in addition to those obtained locally. These were cultivated

* The various more easily obtained membranes used in earlier experiments will be tested in this apparatus shortly.

† In collaboration with the Mycological Section.

PLATE I.

Photo W. Steer.

"Tracks" left by Woolly Aphides on agar medium in a Petri dish. Note: Dead aphides had been removed from this dish—one from end of track in centre of dish.

separately in the usual way on Allington Pippin extract agar. The localities were as follows :

Cambridge, Cambs.	Collected by	F. R. Petherbridge.
Over, Cambs.	,,	,,
Cambridge, Cambs.	,,	A. T. Paskett.
Harpenden, Herts.	,,	C. T. Gimingham.
Slough, Bucks.	,,	A. G. Pollard.
Eltham, Kent.	,,	,,
Kiln Barn, East Malling, Kent.	,,	A. M. Massee.

Colonies of apparently the same filamentous fungus and yeast appeared on each dish, and these two organisms appeared to be the only ones common to all the dishes. Single colonies and growths of both organisms, from aphides derived from two different localities, were sub-cultured on the same medium by the dilution method, and pure cultures were obtained.

The fungus proved to be a species of *Cladosporium*.* No specific difference could be detected microscopically between the individuals constituting the colonies and growths on any of the dishes.

The evidence suggests a close association between Woolly Aphis and a yeast and the fungus *Cladosporium*. The intimate and universal symbiotic relationship which is known to exist between certain aphides and yeasts suggests that some activity of the yeast may be of importance in the nutrition of the aphides. The yeast may possibly pre-digest some part of the food of the aphis, as apparently happens with other insects, e.g., termites. The yeast (or the fungus) under consideration would be of importance in the solution of the main problem only if it happened to digest the substance hypothetically bestowing susceptibility on trees or to be adversely affected by the substance supposedly causing immunity. Experiments are contemplated to test the effects of the two organisms on the constituents of the bark extract and on other constituents of apple trees, to assess their degree of importance to the main problem.

The writers are indebted to W. Steer for the photograph reproduced in Plate I.

Summary.

1. The results of two seasons' work on the nature of immunity from Woolly Aphis of certain varieties of apple stocks are described.

2. The injection of extracts of bark of immune trees into susceptible ones, and conversely, did not affect the reaction of the host to the parasite.

3. Two methods are described for the artificial feeding of Woolly Aphis.

* The fungus has been identified by Miss E. M. Wakefield as *Cladosporium aphidis*.

4. The length of life of the adult insects was apparently unaffected by extracts of either immune or susceptible trees. However, the results of one experiment suggested that the rate of reproduction of Woolly Aphides was depressed more by Northern Spy than by Allington Pippin extract.

5. Woolly Aphides have been kept alive on prepared culture media in Petri dishes for twenty-six days.

6. A yeast and a filamentous fungus have been found associated with the Woolly Aphides from seven different localities.

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Section IV

Mycology and Bacteriology

NOTES ON PLANT DISEASES IN 1928-1930.

By H. WORMALD.

Frost Damage to Pear Trees.

During 1928 a number of pear trees on one of the trial plots of this Station showed large open cracks, exposing the wood. The cracks appeared at, or immediately below, the crutch, and were invariably on the side facing south to south-west. The cracks were first noticed shortly after the severe frosts that occurred about the middle of December, 1927. The damage was most conspicuous on trees of the variety Conference worked on various quince stocks. In particular all the trees in one row of sixteen of this variety on quince B had cracks from one to twelve inches long.

In 1929 a similar feature was noticed on a number of trees in another stock trial plot. Early in November there were frosts on several days. On the 14th of that month many of the trees were cracking at the crutch. The cracks became wide open fissures, two to twelve inches long, in the bark. The damage again was chiefly on the variety Conference, but a few trees of Souvenir du Congrès and of Dr. Jules Guyôt were similarly damaged. As before, the cracking appeared on the side facing south to south-west and it is concluded that the damage was a result of sudden thawing of the frozen bark by the warmth of the afternoon sun.

"Functional" Diseases of Fruit.

Bitter Pit, Drought Spot and Jonathan Spot have been very prevalent during the last three years. In 1928, apples (variety James Grieve) showing conspicuous pitting were received as early as July when the fruit was only half grown. Spotting of apples during storage was common in 1929 and in 1930. An instance of severe spotting of apples during storage was brought to our notice at the end of December, 1929, by a grower in the Weald of Kent, who wrote, "I am sending two Lane's Prince Albert apples, taken from a pocket of about thirty bushels so infected in the middle of a thousand bushel store of them. They are stored about two feet deep on a wooden floor. Only the apples in this pocket show signs of infection; the others are apparently quite sound." On keeping the specimens under laboratory conditions for over a week they showed no further discoloration and the spots were the same size as before, so that there was no definite rot. Although fungal hyphæ were found in some of the spots it was concluded that the damage was not caused by fungal infection. Similar spotting has been attributed to defective respiration

and it would appear that the closely packed fruit in the middle of the store had not had sufficient aëration.

Recent work on Bitter Pit in Australia leads to the conclusion that spotting of fruit in store is sometimes a result of gathering the fruit before what has been named " picking maturity," and it is probable that some of the severe spotting which appeared on stored apples in 1930 was due to their being picked too early.

A notable feature of certain varieties of pears, noticed towards the end of October, 1928, was a disturbance that is known as " Internal Breakdown." This was a discoloration starting at the core and spreading outwards so that pears which were outwardly apparently quite sound and firm were found, when cut open, to be brown and pulpy centrally. Specimens examined were of the varieties Louise Bonne de Jersey, Conference, Beurre Alexandre Lucas, and Nouveau Poiteau. Those of the last named variety (examined on November 12th) were quite soft when received and on cutting them across they were found to be almost completely brown and rotten. No organism could be found associated with the damage in the early stages (before the fruit was finally infested by saprophytic fungi) so there was no evidence that the result was brought about by a parasite. Visitors to the Station said that the trouble was very general that year and that it affected many varieties.

Apples (Allington Pippin, Lane's Prince Albert and Bramley's Seedling) received from Sussex in September, 1930, showed sunken, brown, discoloured bands on the coloured side, so pronounced on some of the fruit as to cause a definite deformation of the apples. A few days later other apples (Allington Pippin) showing similar discoloured bands were received from Cheshire. That the bands were on the coloured side (exposed to the sun) suggests that the damage was a form of Sun Scald although it bears some resemblance to what is known as Crinkle which is said to be a functional disease related to bitter pit.

Apples Cracking.

During the last week of October, 1929, Orleans Reinette apples on the Station were very badly cracked. It was estimated that at least seventy per cent. of the fruit was affected. In many of them the cracking was at the eye, giving a star-shaped appearance to that end of the apple. In others one of the cracks extended the whole length of the apple from the eye to the stalk. Cracking in fruit, at that stage of development, is usually a result of rain following a period of dry weather and this was probably the cause in this instance, but why this particular variety should show it in such a pronounced way is inexplicable.

Apple Trees Dying Out in Heavy Soil.

During May, 1930, complaints were received from two localities in Sussex and one in Essex of apple trees suddenly failing. On most of the affected trees

the leaf buds burst and some came into flower, but early in May the leaves and flowers of some or all the branches wilted and some trees died outright. On such trees some of the roots and usually a portion of the stems had turned brown and gave off a characteristic alcoholic odour. The sub-soil in each of the three localities was distinctly clayey. The plantations in Sussex, where the trouble was particularly severe, were on the Weald Clay. Information received regarding the soil in the Essex plantation was as follows: "The soil for about nine inches down is a friable loam but where we dug a dying tree out we found nine inches of top soil and then about a foot of wet puggy clay, underneath this, clay and stones, not nearly as wet, and apparently well drained, but there is this layer of pug between the top soil and that underneath."

No parasite could be found associated with the dead areas in the roots and stems and the result was probably due to lack of aëration, heavy rains in autumn and spring causing the soil to be so waterlogged that the air in the soil was insufficient for normal respiration in the roots.

Crown Rot of Apple and Pear Trees.

About the middle of November, 1928, roots of cordon pear trees were received from a grower in Suffolk. The letter accompanying the specimens stated: "The trouble started two years ago with some Cox's apple cordons and the ones I replanted with in the same place have likewise gone the same way. The ones I enclose are pear cordons; these were quite healthy up till this April when one that was full of bloom suddenly died and the trouble has now spread along to four or five others. On the trees not quite dead there seems to be a white fungus on the roots." An examination of the roots showed that the "white fungus" was the mycelium of the White Root Rot Fungus, *Rosellinia necatrix*.

A few days later the lower end of the trunk of a fruit tree, together with portions of the main roots, was brought in from an orchard in North Kent. Again there was a parasitic fungus present but in this instance it was the Honey Fungus, *Armillaria mellea*, which attacks forest trees as well as fruit trees. The trees affected were apple, pear and plum, and the disease was generally distributed throughout the orchard.

Apple Canker (*Nectria galligena*).

In addition to infection on standard and bush trees cankers were found on cordons and on young nursery trees. Towards the end of May, 1929, two maiden trees were received from Herefordshire, one a budded tree, the other grafted; they were cankered and in a dying condition, the leaves wilting as the buds began to open. In June, the stem of a three year old tree, also cankered and bearing conidial fructifications of the fungus was received from the

same nursery. The letter accompanying the specimen stated: "The disease seems to enter by way of the lateral shoots—often short spurs which have never been cut; in two or three varieties this is really serious and the trees will be quite useless for sale." Such instances show that canker may be very destructive in the nursery if not checked.

Eye-Rot of Apples and Pears (*Nectria galligena*).

This disease is caused by the canker fungus and is recognized, as the name implies, by a rotting of the tissues round the calyx end thus causing the infected fruit to have a characteristic flattened shape. During August, 1930, apples showing eye-rot were received from two localities in Kent and one in Sussex. One of the apples sent in was a Lane's Prince Albert but all the rest were Worcester Pearmain, a variety which appears to be very susceptible to this disease. Mr. G. C. Johnson (Horticultural Superintendent for East Sussex) kindly supplied the following information about the Sussex outbreak: "The grower informs me that for several years he has been troubled with the disease. This year he has eighty per cent. of his Worcester crop affected. I find that the affected trees are badly cankered on both the old and the young wood."

About the same time a Kentish fruit-grower sent in a number of pears, variety Fertility, infected in the same way.

As eye-rot is caused by the canker fungus the careful cutting out of all cankers so as to prevent the fungus from producing spores will check not only cankering itself but also eye-rot.

Brown Rot Diseases.

Fruit Rot of apples and pears caused by *Sclerotinia fructigena* has been very prevalent during the last three years. The ravages of this fungus are mostly confined to the fruit, but sometimes it extends into the spurs and even the branches. In August, 1928, severe infection by *S. fructigena* was observed on three trees, of the variety Melon, which were growing on the variety trial plot on the Station. Not only was forty per cent. of the fruits infected on these trees but the fungus grew from the fruit into the spurs and also into the branches, producing cankers. The cankers girdled the branches and so caused the death of the parts terminal to the cankers. In 1929 similar cankers were again observed on the same trees but as there was less fruit on them than in 1928 the damage was not so severe and the same kind of injury was found on other varieties. One canker was found on a tree of Cutler Grieve, another on Cox's Orange Pippin and a third on Devonshire Quarrenden, all on the same plot as the Melon trees. Specimens of an unknown variety of apple sent from a Surrey garden also showed cankering of fruiting spurs and branches following severe fruit infection by *S. fructigena*. In July, 1930, the stem of a young cordon apple

tree (variety Lord Lambourne) on this Station was found to be girdled by a canker of this kind.

In an earlier report* a brown rot infection of twigs by *S. cinerea*, on an ornamental cherry tree was mentioned. In May, 1929, a similar infection of an ornamental cherry was observed on specimens received from a tree growing in a village in north Kent. The flowering tips of many branches were withering and the symptoms resembled those of brown rot blossom wilt of Morello cherries. In addition to these withering twigs there were others which had been dead since the previous year and these bore the conidial fructification of *S. cinerea*. On placing some of the twigs recently killed in a moist chamber the Monilia fructification of *S. cinerea* developed on the dead flowers within twenty-four hours. Cultures also of the same fungus were obtained by placing particles of the infected bark on agar plates. There was good reason therefore for assuming that the wilting was caused by infection of the flowers by the spores which developed on the twigs killed during the previous season.

Sooty Blotch.

This disease, which bears great resemblance to one caused by the fungus *Gloeodes pomigena* in America, was noted as being very prevalent on apples in 1927.† The dry summers of 1928 and 1929 apparently checked its spread. In 1928 it did not come under our notice at all. During 1929 it was noted for two localities only. In October of that year Northern Greening apples showing the disease were received from a garden at Rolvenden, where the trees were crowded, and the fruit was said to be severely infected ; pears in the same garden also showed the blotching. In February, 1930, stored Bramley's Seedling apples showing a little blotch came from Ightham.

In 1930 the disease was more widely spread than in the preceding two years, and apples showing Sooty Blotch were received from Kent, Sussex, Worcestershire, Cornwall, Devon and Lancashire, the varieties being Schoolmaster, Cox's Orange Pippin, Bramley's Seedling, Blenheim Orange, Allington Pippin and Christmas Pearmain.‡

The type of disfigurement shown by most of the specimens received at East Malling consists of blotches, generally about a quarter of an inch in diameter, but sometimes they are very numerous and so tend to coalesce and form large patches ; these blotches are usually well-defined, almost circular and with a lens are seen to be studded with black dots which prove to be aggregations of fungal cells.

* Annual Report for 1925 (March, 1927), II. Supplement, p. 78.

† East Malling Research Station, Annual Report for 1926-7 (Oct., 1928), II. Supplement, p. 114.

‡ I am indebted to Dr. G. H. Pethybridge, Mr. A. Beaumont and Mr. L. Ogilvie for sending specimens showing Sooty Blotch.

Other types of blotch have been met with. One forms a thin ill-defined greenish film, without dots as seen with a lens. In another type the dots are again absent and under a low power of the microscope the fungus is seen as a thin film but raised along lines which give a honey-comb or reticulate appearance.

On an apple received from Devon, in addition to the typical blotches there were others more irregular in shape and not so well defined. These bore minute dark bodies visible with a lens but circular in outline and not so dark as those on the more typical blotches. These circular bodies each showed a less dense central spot resembling a pore suggesting that the bodies were incipient fructifications.

A Sooty Blotch was observed on plums (varieties Warwickshire Drooper and Cambridge Gage) in September, 1930. As no reference to the occurrence of this disease on plums could be found, it is believed that it had not previously been recorded. The blotching was similar to that, which, on apples, shows black dots when examined with a lens.

Pear Leaf Blight (*Fabraea maculata*).

In a former report* mention was made of a leaf spot on a young Conference pear tree which was close to a quince tree infected with Leaf Blight. In 1928 a young Fertility pear tree was found to be infected under similar circumstances. One branch of this tree was in contact with those of a quince tree showing severe Leaf Blight. On this pear branch the leaves were also conspicuously spotted while the leaves on that side of the tree furthest from the quince were mostly quite free from infection spots. No fungal fructifications were seen on the pear leaves except on one lesion, although they could be found without difficulty on the quince spots. It would seem that the infection of the pear leaves arose almost solely from the quince spots in this instance and also in that noticed in 1927. In each case only that part of the pear tree in close proximity to the quince was noticeably infected. This, correlated with the rareness of fungal fructifications on the pear leaves, suggests that pear leaves are readily infected by the conidia of the fungus but that infected pear leaves are not themselves a serious source of infection.

Leaf Spot of Currants (*Pseudopeziza Ribis*).

This disease continues to be troublesome on black currants, particularly on Baldwin's Black, and severe infections were noted in 1928 and 1930. In 1928 it appeared early in the season and leaves showing the spotting were received from Paddock Wood during the last week of May. A Devonshire grower writing to us of this disease said : " The spot has appeared in the very late summer and autumn during the last three years and has gradually increased. This year

* East Malling Research Station. Rep. for 1926-7 (Oct., 1928), II. Supplement, p. 115.

(1928) however, it appeared in early June, possibly in May. There was serious defoliation in the beginning of July and the bushes are now (September) almost defoliated except in the young tips."

Some varieties of Red Currants are very susceptible to this leaf spot. During the last week of September, 1928, observations were made on the degree of leaf spot infection on the variety plot of red currants on this Station. Some varieties had much more spotting than others, as the following field notes show :

Wilder : spotting noticeable, but not severe, a little defoliation.
Caucasiche : spotting very severe, one-third of the bushes defoliated.
Raby Castle : severe spotting on some bushes, slight defoliation.
Earliest of Fourlands : no infected leaves.
Utrecht : defoliation very severe ; about half the bushes completely defoliated and the rest had lost many leaves.
Victoria : severe spotting and some defoliation.
Scotch 1, 2 and 3 : these strains were almost free from disease ; on one bush two leaves had spots and the rest were clean.
Houghton Castle : slight spotting.
New Red Dutch : disease noticeable but not severe, slight defoliation.
Abundance : some spotting, slight defoliation.
Versailles : most of the bushes completely defoliated.
Laxton's Perfection : very slight spotting only.
Skinner's Early : spotting very severe, about one-third of the bushes defoliated.
Old Dutch : spotting very severe, about one-third of the bushes defoliated.
Hollande Rouge : spotting and defoliation severe.
La Constante : no spotting.
Cherry : more than half the bushes completely defoliated.
Chenonceau : about one-third of the bushes defoliated.
Fay's Prolific : nearly all the bushes defoliated.
Fertility : most of the bushes defoliated.
Little Croft Beauty : spotting and defoliation severe.
Comet : spotting and defoliation severe.

It will be seen that many of these varieties of red currant are very susceptible to leaf spot, while others, e.g. Earliest of Fourlands, the three Scottish strains and La Constante appear to be markedly resistant.

Ripe Rot of Grapes (*Glomerella cingulata*).*

During September and October, 1930, rotting grapes of the white variety, Muscat of Alexandria, were received at the Station from Hawkhurst, Kent,

* A more detailed account of this disease has been published in *The Gardeners' Chronicle*, Dec. 13th, 1930.

and from Tring, Hertfordshire. The Hawkhurst outbreak was investigated on the spot. It was found that the disease was confined to the muscats and that black varieties growing in the same houses were not infected. On the affected vines most of the bunches had one or more infected grapes and some of the bunches had about half their berries destroyed by the rot. The infected areas showed as sunken purplish patches, at first circular, but gradually extending until the whole of a berry was soft and shrunken.

On the discoloured areas there were present the fructifications of a *Gloeosporium*, conforming to descriptions of *G. fructigenum* (=*G. rufomaculans*), the conidial stage of the ascomycete *Glomerella cingulata*. The conidial fructifications were seen as small pustules (about one-sixtieth of an inch in diameter), projecting in concentric circles from the discoloured areas. From each of these pustules numerous spores were abstricted.

As showing how prolific in spore production the fungus is, an estimation was made of the number of conidia on a single grape. A grape with about one-third of its surface infected was washed with water which soon became cloudy with the spores set free. This water with its suspended spores was diluted until the spores in single drops could be counted conveniently. From this and a calculation of the number of drops in the diluted suspension (together with a test for percentage germination) it was found that the conidia, capable of germination, which were obtained from that one grape, numbered about thirty millions.

Glomerella cingulata is the fungus which causes bitter rot in apples, and for confirmation of the identity of the organism found on the grapes it was isolated in pure culture and inoculated into apples. Within a few days lesions typical of bitter rot appeared at the inoculated spots, the experiment thus confirming results (carried out by American workers) which show that bitter rot of apples and ripe rot of grapes are caused by the same fungus.

Vine Powdery Mildew (*Uncinula necator*).

A bunch of grapes with all the berries infected with the conidial stage of powdery mildew was received early in July, 1930, from Battle, Sussex. The grapes were not half grown, the largest being under half-an-inch in length. The variety was Black Hamburgh. The infected vine was growing in a cool greenhouse which had no top ventilation. This deficiency in ventilation was probably a primary factor conducive to such severe infection.

Other Fungous Diseases.

Other diseases which came under notice during the past three years include the following :

Pear Leaf Blister (*Taphrina bullata*) was present on leaves received from Goudhurst in 1928.

Cherry Leaf Curl (*Exoascus minor*) was observed in May, 1928, on a young tree (variety Newington Black) on this Station ; many leaves were infected on the main branches and on the side shoots of the stem, so the tree was dug up and burnt.

Medlar Cluster Cup Rust (*Gymnosporangium confusum*) was present on a few leaves of a medlar tree on this Station and on a single quince leaf.

Leaf Blotch of medlar, quince and hawthorn, caused by *Sclerotinia Mespili*, *S. Cydoniae* and *S. Crataegi* respectively, was observed at East Malling in 1930 ; these fungi though not often met with in this country are of interest in being related to the brown rot fungi.

Gooseberry Cluster Cup Rust (*Puccinia Pringsheimiana*) is rarely troublesome but in 1929 several enquiries about it were received ; in May specimens of badly deformed berries were sent to us from Ireland, and during June infected gooseberries were sent in from six localities within a few miles of Maidstone.

Strawberry Leaf Scorch (*Diplocarpon Earliana*). Severe infection of the leaves was present in a plantation of strawberries at Barming in July, 1930 ; lesions were also present on the petioles, peduncles and runners ; the variety was Paxton which would appear to be a very susceptible variety.*

Nut Mildew (*Phyllactinia suffulta*). Specimens from cultivated hazels showed the mildew on the bracts and on the stalks of the nuts.

Hop Leaf Spot (*Cercospora cantuariensis*) was found near Alton, Hampshire, in September, 1930.† The only other locality recorded for this fungus is Canterbury where it was discovered in 1922.

Shasta Daisy Leaf Blotch (*Septoria Leucanthemi*) was found at Goudhurst in August, 1930.‡

Leaf Spot of Yucca (*Coniothyrium concentricum*) was present on leaves from an East Malling garden. Some of the spots showed concentric markings and the large spots bore fructifications conforming to descriptions of *Coniothyrium concentricum*.

Leaf Spot of Thuja (*Keithia Thujina*) was found on young trees of *Thuja Lobbi* in a garden at East Malling.

Bacterial Blossom Wilt of Pear Trees.

A blossom infection of pear trees on this Station was noted soon after the trees came in bloom in 1929. The lesions on the infected flowers and spurs contained numerous bacteria and the symptoms were similar to those of a disease which has been studied at the Long Ashton Research Station, and found to be caused by a bacterium named *Bacillus Barkeri*. An organism has been isolated

* This outbreak was brought to my notice by Mr. J. Turnbull.
† Specimens sent to me by Mr. W. Buddin.
‡ Specimens sent to me by Mr. W. M. Ware.

from the diseased material at East Malling; when this was inoculated into young pear fruits by means of punctures it caused blackened lesions but inoculations made on pear flowers have up to the present given negative results. The identity of the organism has not yet been determined. It can be distinguished from *B. Barkeri* by certain cultural characters and it is more nearly related to *Pseudomonas prunicola*, an organism which has been found to cause a bacterial shoot wilt of plum trees.

Bacterial Fruit Rot of Cherries.

Cherries showing blackened lesions which were swarming with bacteria were received from Newington, during the first week of July, 1929. An organism was isolated from the spots and this, when pricked into cherries under laboratory conditions caused lesions, suggesting that the organism isolated is parasitic. During 1930 cherry fruits growing in the open were inoculated with the organism; blackened lesions arose round the inoculated punctures and not at control punctures, thus establishing the parasitic nature of the bacterium. The necessary tests for identifying the organism have not yet been carried out in detail, but it appears to be closely related to *Pseudomonas prunicola*.

A Parasitic Flowering Plant.

In a previous report (for 1925) a species of broomrape was described as a parasite of Pelargonium. It was pointed out that parasitic flowering plants rarely appear in horticultural practice. In August, 1929, onions, received from a Berkshire garden, were found to be infected with a species of dodder (*Cuscuta* sp.) a representative of another genus of parasitic flowering plants found in Britain. The strands (whitish, slender, leafless stems) of the parasite twined round and about the leaves of the onion plant but the actual damage was not serious on the specimens examined.*

Summary.

An account is given of certain plant diseases observed at the East Malling Research Station and on specimens received from growers, during the three years 1928-30. Of non-parasitic diseases mention is made of frost damage, "functional" diseases of fruit, and the dying of fruit trees in heavy soil. Fungous diseases include Eye Rot of apples and pears, Brown Rot Cankers, Sooty Blotch of apples and plums, Leaf Spot of black and of red currants, Ripe Rot of grapes, and vine Powdery Mildew. A bacterial blossom wilt of pear trees and a bacterial fruit rot of cherries are noted.

* Species of dodder have been reported as parasitic on potato haulms.

NOTES ON DISEASES OF THE RASPBERRY, LOGANBERRY AND BLACKBERRY IN 1928-1930.

By R. V. HARRIS.

Blue Stripe Wilt (*Verticillium Dahliae* Kleb.).

Reference has already been made in previous publications to the fact that a certain number of canes of most of the varieties of raspberry grown at the Research Station are killed annually by infection with this disease. The severity of the attack fluctuates and does not necessarily increase season by season. In seasons favourable to the disease it is rare that the proportion of canes killed, of even the most susceptible varieties, is sufficiently large to make the attack economically serious. In June, 1928, however, the majority of the fruiting canes in a plantation on the Weald of Kent were found to be dead or wilting as a result of the infection of the stools with this disease. The plantation consisted of a quarter of an acre of the variety *Bath's Perfection* and one acre of *Reader's Perfection*. The stools of the former variety were more seriously attacked than the latter, the majority being dead or moribund. There was no evidence that the disease was spreading from the *Bath's Perfection* stools to the plantation of *Reader's Perfection*. Most of the canes of a large proportion of stools of the latter variety, although tall and well grown were dead when the visit was made. Such stools were grouped in patches which were distributed evenly over the whole plantation. In August of the same year the plantation was again visited. By this time the *Bath's Perfection* plantation had been grubbed as being quite useless, and very many of the young canes of *Reader's Perfection* were showing severe " leaf striping " symptoms of the disease. Other diseases—Cane-Spot and Mosaic—were noted in this plantation but their attack was very slight and it was clear that the main cause of the deterioration of the stools was Blue Stripe Wilt.

In 1929 a very concentrated attack was recorded on the variety *St. Regis*, recently introduced to the Research Station from America. In July most of the young canes of this variety were infected and became dark-blue in colour. The discoloration took place in a manner quite distinct from that observed on other varieties. Instead of the usual clearly defined blue stripe spreading up the cane from ground level, blue patches appeared in various parts of the cane and these patches eventually coalesced so that the whole cane rapidly became blue and died.

In 1930 the stools of this variety were even more severely attacked. In October fifty per cent. of the young canes of the stools of the Research Station

collection were blue and dead. It would appear that, under the conditions at the Research Station, this variety is so susceptible to Blue Stripe Wilt that it cannot be grown successfully.

Cane-Spot (*Plectodiscella veneta* (Speg.) Burk.) and Spur Blight (*Didymella applanata* Kleb.).

(*a*) *On Raspberry.*

Infections of Cane-Spot causing the maximum damage to the canes must take place early in the season, i.e., April to early July. On the other hand primary symptoms of Spur Blight do not appear till comparatively late in the season, i.e., from July onwards. Cases of serious injury to canes by Cane-Spot alone have been observed, but serious injury by Spur Blight apart from parallel attacks of Cane-Spot has not been observed. At the Research Station, an outstandingly serious infection of Cane-Spot took place in 1928 (affecting the fruiting canes in 1929), and the most concentrated attack of Spur Blight was recorded in 1927, affecting the fruiting cane of 1928. The attack of Cane-Spot in 1927 was considerable but did not damage the canes to a great extent, owing (it is suggested) to the exceptionally dry April and May of that year. The remainder of the season was extremely wet which probably accounts for the large late infection of Cane-Spot and the outstanding attack of Spur Blight.

In 1928 the crop from a plantation of the variety *Reader's Perfection* on the farm of a local grower, was seriously reduced by a combined attack of Spur Blight and Cane-Spot in 1927. The upper portion of many fruiting canes on this plantation died, and many of the buds on the canes failed to produce fruiting laterals. In 1928 the very serious attack of Cane-Spot on susceptible varieties at the Research Station was clearly related to the large amount of rain in April, May, June and July. The crop on the variety *Baumforth B* in 1929 was greatly reduced as a result of this attack. Definite indications were obtained on the experimental plots at the Research Station, that the serious effect of the disease on the canes of this variety in 1928 was increased by the severe frosts in the late winter of 1928-29. The susceptibility of the canes to frost injury was increased by infections of Cane-Spot. Where the attack of Cane-Spot was reduced by spraying, the effect of the frost was negligible. In 1929 the attack of Cane-Spot was markedly less in intensity than in the previous year, and in 1930 it increased in intensity although it was not so great as in 1928.

(*b*) *On Loganberry.*

Many complaints have been received of late from loganberry growers in the Weald of Kent to the effect that, in recent years, the crop yield of their plantations has fallen off considerably. Investigation of such cases has shown that this is,

in many instances, largely due to serious infections of the bines by *Plectodiscella veneta* and *Didymella applanata*. Heavy attacks of both these diseases were recorded on loganberries in 1927 and 1928, affecting the crops of 1928 and 1929 respectively. A spotting of leaves of the loganberry due to infection by *Plectodiscella veneta* is very common; in fact the author has yet to see a plantation where the leaves are not infected by this fungus, but in the case of the attacks referred to above, the bines themselves were infected in addition to the leaves, and cankers were formed on the main stems and on the fruiting laterals, resulting in a failure of many of the bine buds to form fruiting laterals, a non-setting of many of the flowers, and a poor development of the berries. Early infections were also commonly associated with a stunting of the growth of the young bines which were in consequence, stimulated to branch. In 1927 and again in 1928 large basal cankers caused by infection with *Didymella applanata* were also commonly recorded and there was no doubt in such cases that the symptoms described above were intensified by such infection. In 1928 a preliminary attempt was made to control Cane-Spot on loganberries by spraying with lime-sulphur on a seriously infected plantation on the Weald. Records made subsequently, on sprayed and unsprayed hills, showed that the spraying resulted in a considerable reduction of the intensity of the attack of the disease on the bines. Further spraying experiments are contemplated.

Cane Blight of Raspberries (*Leptosphaeria Coniothyrium* (Fuckel) Sacc.).

In the spring of 1929 the writer was asked to examine a large plantation of the variety *Bath's Perfection* near Tonbridge, Kent. This plantation was planted in 1920 and in subsequent years had yielded exceptionally large crops. Four years previously to the writer's visit it was noticed that a few of the fruiting canes died before cropping and since that time an increasing number of canes died in a similar way each year. When the plantation was examined it was found that the stools were exceptionally vigorous and the canes well grown but a large proportion were in a moribund condition. Numbers of these canes were examined and in each case there was found, usually at the base, a large cankered area bearing pycnidia answering to descriptions of *Coniothyrium Fuckelii* Sacc. Later in the year inoculation experiments were carried out which established the fact that this fungus was the cause of the disease. In 1930 a further serious outbreak of the disease occurred on the same plantation and on another plantation of the variety *Reader's Perfection* on a farm at East Malling. During this year, perithecia, conforming closely to descriptions of *Leptosphaeria Coniothyrium*, were found associated with the pycnidia on the cankers. Specimens of canes showing similar fructifications were also forwarded from the Plant Pathological Laboratory of the Ministry of Agriculture and Fisheries. These fructifications were found to give rise, in artificial culture, to a mycelium indistinguishable from

that obtained from the pycnospores. It is proposed shortly to test the possible connection between these two types of fructification by inoculation experiments.

One other feature of interest might be mentioned. In both the localities mentioned, large numbers of larvæ of the Raspberry Cane Midge (*Thomasiniana theobaldi* Barnes) were found on the cankered areas. It is intended later, in collaboration with the Entomological Section, to determine the nature of the relation of the Midge to the disease.

In 1930 the same fungus was found on the variety *Lloyd George*. Experiments on the control of the disease have been initiated.

Other Fungi Associated with Diseased Raspberry Canes.

Black Blotch Disease.

In July, 1928, specimen raspberry canes received from Dr. W. A. Millard of Leeds University were found to be covered with black spots and blotches. These spots were not sunken as in the Cane-Spot disease but were quite superficial. Associated with these spots was a fungus corresponding closely to descriptions of *Cryptosporium minimum* Laub., a parasite of rambler roses. This fungus was subsequently isolated in pure culture and preliminary inoculation experiments were carried out which indicate that it is parasitic to a small degree. Symptoms similar to those described above, however, have not yet been reproduced. Later in the year, and in 1930, further specimens of canes infected in a similar manner, were received from Middlesex and Somerset.

There is no evidence that this disease causes serious damage to the canes.

Microthyriella Rubi.

In June, 1928, it was noticed that the surface of the majority of the fruiting canes of the variety *Reader's Perfection* in the plantation on the Weald severely affected with Blue Stripe Wilt and mentioned above, was covered with minute discs averaging 200μ in diameter. These were found to be ascocarps of a fungus corresponding to descriptions of *Microthyriella Rubi*.* This fungus was subsequently isolated in pure culture but inoculations have, up to the time of writing, yielded negative results. There was no evidence to suggest that the infection was in any way responsible for the death of the canes in the affected plantation.

Botrytis Rot (*Botrytis cinerea*).

In December, 1927, a specimen of *Lloyd George* canes was received from a grower in the Midlands who complained that a four acre plantation of this variety was badly attacked by a disease which was killing off many of the canes. It was found that the dead portion of these canes was infected with a strain of

* I am indebted for the identification of this fungus and of *Cryptosporium minimum* to Miss E. M. Wakefield of the Herbarium, Royal Botanic Gardens, Kew.

Botrytis cinerea. Large sclerotia of this fungus were imbedded in the cortex of the canes; these became detached in the spring of 1928 and fell into the soil. Inoculations with pure cultures of the fungus carried out in 1928 showed it to be strongly parasitic. The grower was advised to cut out and burn all dead and dying canes as early as possible. This was done, and a serious attack of the disease has not recurred. It is suggested that the spread of the disease in 1927 was encouraged by the excessively wet weather during the growing season of that year.

Frost Injury to Raspberries and Blackberries.

Plantations of the "Cut-leaved" Blackberry and the Himalaya Berry, in the neighbourhood of Chilham (near Canterbury) and Faversham, suffered considerably as a result of direct injury by the severe frosts in the spring of 1928. At Chilham the degree of severity of the attack was clearly related to the conformation of the ground. Part of the plantation was situated in a hollow, and dead bines on these plants were more numerous than on the plants situated on higher ground. At Faversham the affected plantation was situated on an exposed plateau and the damage was very serious, the majority of the fruiting bines of 1928 being killed.

In both neighbourhoods, plantations of raspberries were also seriously attacked. The symptoms of these attacks are quite distinctive. The upper part of the cane is the first to show signs of injury. The buds in this region fail to grow out and on cutting the stem the cortex is found to be discoloured. This discoloration only extends to the wood at a much later stage. The following were the susceptible varieties of raspberry: *Pyne's Royal, Lloyd George, Devon,* and *Laxton's Abundance*. Plantations of the varieties *Pyne's Royal* and *Lloyd George* at the Research Station also showed symptoms of frost injury in 1928. The instance at the Research Station of severe frost injury in the late winter of 1928-29 to the variety *Baumforth Seedling B*, following severe Cane-Spot infection in 1928, has already been noted.

Black Root-Rot of the Lloyd George Raspberry.

During the early part of the season of 1930 we were asked to examine cases of a "die-back" disease of raspberries, mainly affecting the variety *Lloyd George*. This disease was widely distributed, outbreaks being reported in Cheshire, Worcester, Hampshire and East Sussex, in addition to four widely separated localities in Kent. The growers in question complained that many of the fruiting canes in their plantations were not developing normally. Either the buds failed to grow out at all or the laterals withered at an early stage in their development. Subsequently such canes died. An examination of large numbers of affected stools showed that the primary symptom of the disease was a rotting of a

portion of the crown tissue, accompanied by the death of part of the root system. In exceptional cases the whole stool was thus affected. This was followed by the slow discoloration of the tissues of the canes associated with the affected portion of the crown, and ultimately by the death of these canes. Later in the year the symptoms of the disease became less noticeable, and stools partially affected produced vigorous spawn and showed signs of apparent recovery. A species of *Fusarium* was found in constant association with the rotting crown tissues although, usually, other organisms were also present. This fungus was isolated but inoculations of healthy plants with pure cultures have, up to the present, yielded negative results. On the other hand symptoms similar to those observed in the field have been induced on plants in pots by water-logging the soil. Further, an examination of affected plantations showed that in every case the plants were growing in very wet soil, and there was evidence that the conditions for the normal production of root fibre were poor. Reports on cases in other parts of the country agreed with the local cases in this respect. These facts together with the subsequent apparent recovery of partially affected stools, suggest that the disease was largely brought about by unfavourable conditions developing in heavy wet types of soil as a result of the excessive drought of 1929 followed by the heavy rains and lack of frost action in the winter of 1929-30. Any cultural process therefore, tending to improve the aëration of the roots, such as ploughing a deep furrow between the rows in the winter, followed by intensive cultivation later, is to be recommended as a control measure.

Diseases of Blackberry caused by species of Septoria.

In March, 1930, the writer was asked to examine a plantation of blackberries near Maidstone the bines of which were not developing normally. Large numbers of the buds were found to be dead, and long tracts of the bines were therefore sterile. Associated with these dead buds were large purple blotches, which were covered with pycnidia of a species of *Septoria*. This fungus was found to differ from the species of *Septoria* commonly found on species of Rubus and referred to below. The presence of this fungus on the blotches was so constant that there is strong presumptive evidence that it is the cause of the disease. The result of inoculations of plants with pure cultures of this fungus carried out in 1930, however, are not completely conclusive and they will be repeated in 1931. There was very striking evidence on the affected plantation that the serious infection of the bines was largely due to the method of training them. An attempt in control by modifications of these cultural treatments is in progress.

Numerous cases of a leaf and bine spot of blackberries associated with a species of *Septoria* differing from the above in the size of its spores and answering

to descriptions of *Septoria Rubi* have been observed. A recent case where the spotting was exceedingly prevalent was recorded on a plantation of the Himalaya Berry, near Maidstone, and the fungus was isolated in pure culture for comparison with the species associated with the Purple Blotch disease mentioned above.

Blackberry Rust (*Phragmidium violaceum* Wint.).

A very serious attack of this rust was recorded in 1929 on the plantation affected with the Septoria Purple Blotch disease mentioned above. A large proportion of the flower receptacles and berries were infected and much of the fruit was rendered unsaleable. Considerable premature defoliation of the hills also took place owing to leaf infection.

In July, 1930, numbers of rust infections of the stems were found. It has not yet been determined whether such lesions are the result of infection the previous year, but in October of the same year a number of minute incipient rust infections were recorded on the young and tender tips of the new bines.

Summary.

1. Features of interest in the investigation of the following diseases of species of Rubus during the seasons of 1928, 1929 and 1930 are summarized.

2. *Raspberry diseases:* Blue Stripe Wilt (*Verticillium Dahliae* Kleb.); Cane-Spot (*Plectodiscella veneta* (Speg.) Burk.); Spur Blight (*Leptosphaeria Coniothyrium* (Fuckel) Sacc.); Botrytis Rot (*B. cinerea.*); Black Blotch (? *Cryptosporium minimum* Laub.); *Microthyriella Rubi:* Frost Injury and Black Root Rot.

3. *Loganberry diseases:* Cane-Spot (*Plectodiscella veneta* (Speg.) Burk.); and Spur Blight (*Didymella applanata.* Kleb.).

4. *Blackberry diseases:* Purple Blotch (*Septoria* sp.); Septoria spot (*S. Rubi* ?); Rust (*Phragmidium violaceum* Wint.) and Frost Injury.

THE CROWN-GALL DISEASE OF NURSERY STOCKS.

II. THE RELATIVE SUSCEPTIBILITY OF APPLE STOCKS TO CROWN-GALL.

A Progress Report.

By R. V. HARRIS.

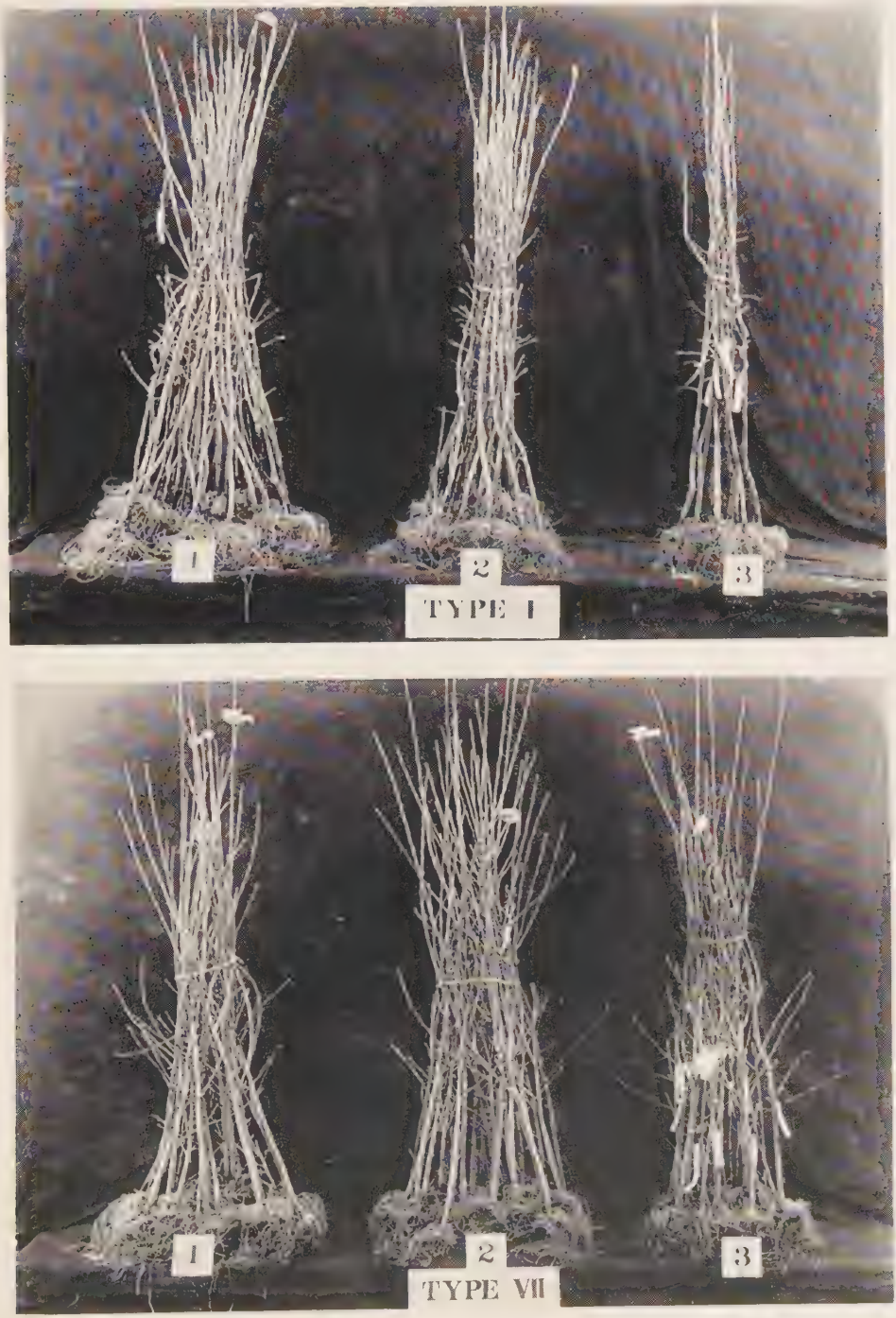
In a paper by Wormald and Grubb published in 1924* observations in the field on the relative susceptibility of apple stocks to natural infections of crown-gall were summarized. These observations which extended over four years were "chiefly directed to galls occurring on 'layered' apple stocks either grafted or not grafted, at the end of the second or third season after their removal from the parent stools," and it was concluded that "the different varieties of layered stocks differ widely in their susceptibility to crown-gall." The writers then proceeded to classify the varieties of stocks into three groups with regard to their susceptibility to the disease, namely a first or "very susceptible" group, a second or moderately susceptible group and a third or "moderately resistant" group. In discussing the causes underlying the observed differences in susceptibility, it was concluded that there is an apparent positive correlation between the difficulty with which a particular variety of stock is induced to root and its degree of susceptibility. "The varieties of apple stocks which root with difficulty, show a relatively high degree of susceptibility." But it was pointed out that "this difference in rooting and the necessity for tearing shy rooting stocks from the stools, will not account for all the differences in susceptibility." "Type VII for instance, is much more easily rooted than No. 51 and somewhat more readily than Type II, yet it has invariably been the most susceptible."

The experiment to be described in this report was carried out in 1929 and is the first of a series designed to determine the relative inherent susceptibility of varieties of stocks by artificial inoculation under controlled conditions.

Methods.

It was decided to limit this experiment to two varieties of stock and to use a large unit (100 trees) of each, in order to determine the minimum size of the units to be used in future experiments. The two varieties used were No. VII, classified by Wormald and Grubb in their first or "very susceptible" group, and No. I belonging to the third or "moderately resistant" group. The two units of 100 trees each consisted of one-year bedded material, i.e. the trees had been planted out for one year after their detachment from the stools; they were

* "The Crown-Gall Disease of Nursery Stocks."—I. Field Observations on Apple Stocks. *Annals of Applied Biology*, 1924, **11.** 278-291.



One hundred each of No. I and No. VII stocks inoculated with pure cultures of *Bacterium tumefaciens* and graded according to the incidence and size of the resultant galls.

Group 1. Stocks free from galls.
Group 2. Stocks with galls of mean diameter not greater than 1 cm.
Group 3. Stocks with galls of mean diameter greater than 1 cm.

An inoculated No. VII stock showing a resulting gall classified in category 6. (See table.)

therefore strictly comparable. Each tree was planted in a 7 inch pot during the first week in March, 1929. The soil used for potting, a moderately rich compost in common use in the glasshouses, was partially sterilized by steam before use. This soil was packed into the pots to a depth of 3 inches from the top, and the remainder was filled with sterilized silver sand. After potting, the plants were kept in a cool greenhouse throughout the growing season.

On May 9th, 1929, each of the 200 trees was inoculated in the crown with pure cultures of *Bacterium tumefaciens*. The strain used was one isolated from a raspberry gall by Dr. H. Wormald and it had been proved by inoculation experiments to be pathogenic on apple trees. Galls have not yet been reproduced on apple trees by inoculation with organisms isolated from apple galls at East Malling. Streak cultures of the raspberry strain were made on slants of carrot extract agar and were incubated for three days before the inoculations were made. The layer of sand in each pot was removed, thus exposing the crown of the tree, and any sand adhering to the crown was washed away. A tangential cut was then made in the cortex of the crown with a sterile scalpel and the surface thus exposed was covered with a loopful of the bacterial slime; the tongue of bark made by the cut was then pressed back into position. The inoculated wound was covered with a pad of cotton wool and the pot was refilled with partially sterilized soil.

RESULTS.

On December 18th, 1929, records were made of the incidence of galls, on each of the inoculated trees. Each tree was removed from its pot and the soil was washed away from the roots. The presence or absence of galls was recorded and each gall was placed in a category according to its mean diameter. The length of the current year's shoots was also recorded in order to determine whether the incidence of galls was related to any decrease in the vigour of growth of the infected tree. These records are summarized in the following table:—

Variety of Stock.	Total Percentage of trees with galls.	Percentage of trees with galls classified according to size of galls.						Average length of new shoot growth per tree.	
		Mean diameter (cms.)						Normal trees.	Trees with galls.
		(1) 0 to 0.5.	(2) 0.5 to 1.0.	(3) 1.0 to 1.5.	(4) 1.5 to 2.0.	(5) 2.0 to 2.5.	(6) 2.5 to 3.0.		
								cms.	cms.
I	36	17	11	5	3	—	—	106	109
VII	67	21	22	13	4	3	4	149	162

It will be seen from this table that under the conditions of the experiment the susceptibility of stock No. VII to the inoculations was considerably greater than that of No. I both as regards the percentage of successful infections and the size of the resultant galls. For example, whereas 24 per cent. of the No. VII stocks developed galls exceeding 1 cm. in diameter only 8 per cent. of the No. I stocks developed galls of this order of size. This confirms the observations in the field of Wormald and Grubb who state that " some varieties show year after year not only a higher proportion of galled stocks or trees but also larger galls than others."

It will also be noted that in the case of both varieties of stock the length of new shoot produced during the year of inoculation by trees with galls did not differ significantly from the length of new shoots produced by normal trees.

On the basis of the above experiment more extended experiments were carried out in 1930 to compare the susceptibility of stocks Nos. I, II, VII, IX and XVI under similar conditions. The results of these experiments although not yet completely available, confirm the results of the above experiment with regard to the relative susceptibility of stocks Nos. I and VII.

Summary.

1. An account is given of the first of a series of experiments, commenced in 1929, designed to determine the relative inherent susceptibility of apple stocks to crown-gall (*Bacterium tumefaciens*) by inoculating them with pure cultures of the organism under controlled conditions.

2. In this experiment stock No. VII was markedly more susceptible than No. I, both with regard to the relative number of successful inoculations and to the size of the resultant galls.

SOME DISEASES OF WALNUTS.

By J. B. HAMOND.

I. Walnut Bacterial Blight.

This disease, which causes much loss in the walnut growing areas of California, was observed on a tree at the East Malling Research Station in 1925. The characteristic symptoms are seen on young growing parts of the tree. The disease is usually noticed first on the leaves, which show small, black, angular spots, about 0.5 mm. in diameter. These spots are found to contain numerous bacterial rods. On the young stems and petioles the bacteria are present in sunken, blackened areas in which the tissue is killed inwardly to the pith. The organism which has been isolated from these stem lesions and leaf spots has been found by cultural tests and inoculation experiments to be the bacterium *Pseudomonas Juglandis*.

It has been noticed that the first leaves to become attacked in the spring do not show the typical spotting but are contorted and show spots at the margins only. The organism isolated from these marginal spots has been shown by cultural tests to be the same bacterium as is present in the typical spots produced later in the season. Early this summer a plant with contorted leaves showing the marginal spot was arranged above a clean seedling walnut in a cool greenhouse. The infected plant was then sprayed from above with water from a fine nozzle for several hours on each of five successive days, the object of this being to ascertain whether the primary marginal leaf spots may be the sources from which later infection arises. After an incubation period of about a fortnight, typical black spots were produced on leaf blades of the previously uninfected plant, as well as on leaves of the other plant which were clean when the experiment commenced. As would be expected, the infection was most pronounced on leaflets which were directly beneath the contorted ones, thus suggesting that the marginal spot precedes the typical infection and that under natural conditions the bacteria are most probably washed from leaf to leaf during rain.

The diseased shoots of the previous year are believed to be the source of initial infection each spring. Last February, however, while the trees were still dormant, great care was taken to cut out all the old lesions on trees in the nursery beds. In spite of this precaution the disease appeared in the spring. In several cases all the leaves from a single bud were attacked as they unfolded, while leaves from other buds on the same tree were clean at this stage. This

suggests that the organism may overwinter in the bud scales as well as in the old stem lesions.

Bacteria probably enter healthy tissues by means of the stomata. If a shoot is injured so that the epidermis is broken the organism can enter anywhere over the injured surface and is not limited to the stomata.

In the year 1929 the nursery trees were tied to supports by means of string. In many cases the trees swayed in the wind, with the result that the string cut into the stems. A survey of the trees was taken in the autumn of 1929, and it was found that nearly 25 per cent. of the bacterial stem lesions occurred at wounds where the stems had been tied to supports. In 1930, sacking was placed between the tree and support before tying, so that injury from the string and the resulting bacterial lesions were avoided. Inoculation experiments have shown that the organism can readily infect young shoots through wounds, thus confirming these observations.

Last winter bacteria were isolated from stem lesions in the months of December, January, February and March, thus showing that the organism can overwinter in the stems and is then ready to reinfect the young growth as soon as it appears in spring.

This year an attempt was made to control this bacterial disease by spraying the trees with Bordeaux mixture. The first application was given in the middle of May, using Bordeaux mixture at a strength of 8 : 8 : 100. As a result of this most of the trees showed spray injury in the form of marginal leaf scorch during the next week. About a month later the trees were sprayed again. This time the excess-lime formula was used and the Bordeaux mixture was applied at a strength of 8 : 25 : 100. There was no scorching of the leaves as a result of this spray. A third application was given in the middle of July when all the trees had come into full leaf. The excess lime formula was again used.

During the summer observations were made from time to time but no difference in the prevalence of blight on the sprayed and unsprayed trees could be seen. There was no evidence therefore that three sprayings with Bordeaux mixture gives any protection against blight infection.

Previously this disease has only been known on nursery trees at East Malling, but this summer (1930) walnut blight has been found on two established trees in this country. One of these trees is situated in Worcester and the other in Kent. Both trees showed typical spotting of the leaves, but in neither case was the attack bad enough to infect the nuts. The organism was isolated from leaf spots from both trees and grown in pure culture. In each case the growth produced was typical of *Pseudomonas Juglandis*. Inoculations were made (with strains from both trees) on grafted and seedling plants in a cool greenhouse. The plants were punctured near the apices of shoots and at the bases of petioles ; then bacterial slime consisting of one day's growth of the organism was placed

on the punctures and the inoculated regions were sprayed with sterile water. Control shoots on the same and on different plants were treated similarly but not inoculated.

Three weeks later the inoculated shoots showed infection at all the punctures as seen by discoloration and typical water-soaked appearance. The control punctures showed no blackening, and healed up normally. As a result of these inoculations it is concluded that the organisms present in the leaf spots on both the established trees are pathogenic.

It would appear then that this disease is not confined to nursery trees in this country, and as it may under certain conditions become disastrous to walnut cultivation a knowledge of its distribution is desirable. Those who possess walnut trees are asked therefore to examine their trees for the symptoms described and to send to this Station specimens showing suspected symptoms. As indicated above, it is characterized by numerous, very small, angular black spots on the leaves, and is thus distinguished from the more common leaf blotch (described below) in which the lesions are larger, more scattered and brown rather than black.

II. Walnut Leaf Blotch.

This is one of the most common diseases of walnuts in this country, and it has often been confused with walnut bacterial blight. The parasite in this case is a fungus, so that microscopically there is no difficulty in distinguishing the two pests.

The disease is characterized by large brown patches which are produced on the leaves. These patches are yellowish brown on the upper surface and greyish in colour below. The conidial fructifications of the fungus, which is known as *Marssonia Juglandis*, appear as small black specks all over the dead patches on the leaves. Similar fructifications are formed on the green shuck which surrounds the young nut.

The fungus passes the winter as a saprophyte on the dead walnut leaves. In the spring the characteristic perithecia of *Gnomonia leptostyla*, which is the perfect stage of *Marssonia Juglandis*, appear on the dead leaves.

Last autumn some walnut leaves thickly covered with conidial fructifications of *Marssonia Juglandis* were placed in a shallow wooden box the sides and top of which had been removed and replaced by coarse-meshed wire netting. The box of leaves was left in an exposed position so that the leaves were as far as possible under natural conditions.

The following March the leaves in the box were examined and it was found that numerous perithecia were present. There was no difficulty in identifying these perithecia on account of their characteristic, projecting beaks which were

visible to the naked eye as tiny points sticking up all over the upper surface of the infected leaves.

On cutting sections through these perithecia they were found to contain numerous asci. Each ascus contained eight ascospores, which in some cases were ripe and ready to exude through the beak-like ostioles. These ascospores reinfect the young leaves in spring, giving rise to the conidial stage of the fungus.

This disease is rarely of economic importance on the leaves, but a bad attack, early in the season, may cause premature leaf fall and a consequent decrease in the crop. The fungus often does much damage to the green shuck of nuts that are ready for pickling. The brown patches on which the fructifications of *Marssonia Juglandis* are situated may form hardened areas which penetrate the entire shuck and detract from the appearance and therefore from the commercial value of nuts at the pickling stage.

As the only means of reinfection in spring is by ascospores which are produced in perithecia on dead leaves, the best control for this disease is to collect and burn all infected leaves as soon as they fall.

III. Die-back.

This year a number of walnut trees have been noticed on which one or more shoots have died back. This trouble has frequently been seen on old established trees, on seedling trees planted out and on young grafted trees. Some of the grafted trees have died back almost to the junction between stock and scion. The dead shoots become thickly studded with pustules which prove to be fungal fructifications. Two types of fructifications are found on such dead shoots. One of these conforms to descriptions of *Cytospora Juglandina* and the other to the Phomopsis stage of *Diaporthe perniciosa*. No inoculation experiments have yet been carried out to test the parasitism of these fungi.

IV. A Disease Following Grafting.

This year many of the trees grafted under glass in the spring failed to form a union between stock and scion. On examination of some of these grafts numerous dark brown, powdery spores were seen at the cut surfaces between stock and scion, many of them invading the pith, which appeared quite black in consequence.

Transverse sections were cut which included the diseased and healthy tissue. Dead areas in the wood were found to consist of cells packed with thick-walled hyphæ, which were chiefly found in the medullary rays. Fine hyphal threads were also present running through living cells. The dark brown spores were circular or somewhat irregular in outline, very thick-walled and about 15 μ in diameter. Spores were produced profusely at the cut surfaces of stock and scion and were also present in many of the vessels. Several hyphæ were

observed which were swollen at the tips; these enlarged tips may be immature spores which will finally be budded off.

No definite fructifications were present, but when the fungus was grown in pure culture the dark spore-like bodies were seen to be produced from the hyphal cells, so they are probably of the nature of chlamydospores. In culture a number of smaller, hyaline, rod-shaped conidia also developed endogenously. It was first thought that these rod-shaped spores were a contamination, but the regularity with which they were produced with the usual precautions taken to keep the cultures pure, made it more likely that they were a stage in the life history of the fungus.

Young seedling and grafted walnut trees growing in a cool greenhouse were inoculated with pure cultures of the fungus. Two seedling plants were inoculated about half way up the stem, and two grafted plants were inoculated at the junction between stock and scion. In every case a T-shaped incision was made which cut into the wood; the tissue was then raised and a piece of mycelium inserted. The wound was then bound round with sterile cotton wool and tied with raffia. Grafted and seedling plants were used for control and were treated in the same way but not inoculated.

After a week the plants were examined and the fungus was found to be producing a white growth at the points of inoculation. The slits in the stem of the control plants were healing up normally.

A fortnight after inoculation the fungus was growing well in all the inoculated plants and had produced the characteristic dark brown circular spores. The controls appeared healthy.

The relation that this organism bears to the failure of the grafts has not yet been determined, but in these preliminary experiments the fungus invaded inoculated trees and produced its characteristic dark spores while control trees remained healthy. It is believed, therefore, that the organism is parasitic but further work is necessary to obtain confirmation of this.

The identity of the fungus has not yet been determined, but the dark, thick-walled conidia associated with the endogenously produced hyaline conidia suggest that it is a species of *Thielaviopsis*.

V. Fungi Found on Walnuts in Store.

Fresh nuts, if not cleaned and subjected to drying, quickly develop moulds on the surface. For this reason, if nuts are to be stored in the fresh condition, they should have some preliminary treatment.

Walnuts are harvested from the ground. In order to avoid leaving the nuts hanging too long on the trees it is desirable to shake the trees regularly. When the nuts fall to the ground the shuck should be green and firm but ready to drop away from the nut. If the nuts are allowed to lie on the ground the

shuck quickly becomes black and sodden. In this condition it is difficult to remove from the nut, causing it to become discoloured and encouraging the growth of moulds.

After harvesting the nuts, care should be taken to remove every trace of the green shuck. It may be necessary to scrub the nuts in order to do this thoroughly. Where walnuts are grown on a large scale mechanical washers have been constructed for this purpose. It is important that the nuts should not come in contact with water more than is absolutely necessary, as this causes those that are poorly sealed to crack open.

The nuts are dried as rapidly as possible. This is most successfully achieved by placing them in single layers and exposing them to a draught. Exposure to a sudden high temperature is not desirable, as rapid shrinkage causes cracking of poorly sealed shells.

Nuts that are to be stored in the fresh condition may now be bleached. If the nuts are bleached in chloride of lime solution or 2 per cent. sodium sulphite for two to three minutes before storing they are much improved in appearance and are more resistant to fungi.

The nuts have been found to keep well if stored in coconut fibre, peat moss fibre or salt. Earthenware crocks are filled with alternate layers of nuts and the storage medium until they are full. The degree of dampness of the fibre should be such that the plumpness of the kernels is maintained, without endangering the cracking open of the shells and the growth of moulds which will result if the medium is too damp.

The crocks are stored in a cool, dry cellar. A temperature of a few degrees above freezing point has been found to be successful.

When fungi develop on nuts in store they appear first in crevices on the shells where spores can easily lodge ; moulds also appear early at the suture between the two halves of a nutshell for the same reason. Fungal threads are also certain to be found on any trace of shuck which may still be present on the shell. Once having obtained a foothold, rapidly growing fungi such as *Penicillium* sp. and *Botrytis cinerea* quickly cover the whole surface of the shell.

Fungi on the outside of a nutshell are not of much importance compared with those found in infected kernels. It has been found that fungal threads can pass through the shell and then attack the kernel. Transverse sections of an infected walnut shell showed mycelium passing through and around the wood fibres of which a walnut shell is composed, finally passing from the outside to the inner surface of the shell. Although it has been proved possible for fungi to pass through nutshells, mycelium chiefly spreads through the suture of shells which are badly sealed. Therefore, by taking the precautions mentioned above to keep the shells uncracked, a great deal has been done to ensure that the kernels will be kept clean.

The following lists give some idea of the variety of fungi found on stored walnuts. The fungi are placed in order of frequency in which they occurred.

Fungi found on the shells were : *Penicillium* sp., *Botrytis cinerea, Cladosporium* sp., *Mucor* sp., *Rhizopus nigricans, Pachybasium* sp., *Fusarium* sp., *Coniothecium* sp., *Alternaria* sp., *Pestalozzia Hartigii, Stysanus Stemonites.*

Fungi found on the kernels were : *Penicillium* sp., *Botrytis cinerea, Mucor* sp., *Rhizopus nigricans.*

Summary.

An experiment is described which suggests that a marginal leaf spot precedes the typical leaf spot in walnut bacterial blight. To prevent spread of blight, the importance of keeping a tree uninjured is emphasized. The disease has now been found on two established walnut trees in England.

Observations on the ascigerous stage of *Gnomonia leptostyla* are given.

Cytospora Juglandina and *Diaporthe perniciosa* are frequently associated with die-back.

Observations on a fungus parasitic on walnut grafts are given. The fungus is probably a species of *Thielaviopsis.*

Suggestions are made for keeping stored walnuts, and lists of fungi found on shells and kernels are added.

Addendum.

While this article was in the press further observations have shown that the walnut graft fungus belongs to the genus *Chalaropsis*, distinguished from *Thielaviopsis* by its terminal macrospores. A culture was therefore sent to Professor Peyronel who has described *Chalaropsis thielavioides* as a parasite of lupins in Italy. Professor Peyronel kindly examined the culture and replied that the walnut graft fungus is the same as the one he found on lupins.

INVESTIGATIONS ON CONIOTHECIUM.

A Progress Report.

By M. H. MOORE.

The necessity for the present investigation has been shown by the writer's studies on the incidence and control of Apple Scab, published elsewhere (12). Special consideration was given to fruit injury caused by applications of Bordeaux mixture and appearing as a fine, superficial russeting or as a serious blemish in the form of cracking and general distortion. Similar injury was observed, however, on fruits from "control" trees unsprayed, or sprayed with lead arsenate only, although in this case the extent of the injury was not so great as where Bordeaux mixture was used. The writer found from enquiries made among other observers and among certain growers that it was generally assumed that such injury appeared as a result of prevailing climatic conditions, especially the occurrence of frosts in the spring. On referring to the literature on the subject, it was found that symptoms similar to those observed at East Malling had, indeed, been recorded as being of seasonal occurrence. For example, Carne (4) states that in Australia the cracking and russeting found in the apple variety Dunn's is connected with climatic and growth conditions. Goodwin (6), referring to similar symptoms in the same variety, is of the opinion that the injury may be regarded as being due more to general debility of the tree than to other causes. More recently Young (16), in discussing frost damage and means of preventing it, notes that pear and apple fruits grown in the United States of America frequently show "a coarse, woody, russet tissue, which covers a portion or even the entire outside of the fruit," and he attributes this state to damage by frost. Tetley (15), who has made detailed studies of the epidermal structure of the apple, writes, "Extensive cracking occurred in the summer of 1928 in the varieties James Grieve and Beauty of Bath as early as the beginning of June. Most of the cracks were formed on the sunny side of the apple. A long, dry, cold period when the fruit was setting had been followed by a warm, rainy period when the apple was ready to swell. The cold period had produced a comparatively thick and unelastic type of cuticle, especially on the exposed side of the apple, with the result that the epidermis was unable to resist the rapid swelling of the cells within, and had consequently cracked. These cracks had been healed by cork formation of a rather irregular nature with only a light suberin deposit on the cell walls. Cox's Orange Pippin is one

of the commonest varieties to show the condition known as russeting which is closely bound up with cork formation. The extent of the russeting varies considerably from season to season and some varieties in this country never become russeted, although they may be exposed to conditions similar to those producing russeting in another variety."

MacDaniels and Heinicke (9), referring to the authority of Heald (8), draw attention to the fact that the russeting of apples resulting from frost injury can quite easily be confused with that resulting from spraying the trees with lime-sulphur in hot weather (8, p. 220) or with Bordeaux mixture in damp, cloudy weather (8, p. 215). " Under some conditions, however, russeting is known to be produced by late spring freezes or frosts occurring after petal-fall, entirely apart from the common forms of spray injury " (8, p. 213).

In October, 1928, the present writer's attention was drawn to the crop of Allington Pippin apples which had been recently picked at the East Malling Research Station. Prominent star-shaped markings were present on the skin of all the fruits examined, and further investigation showed that these were caused by the rupture of the skin radially from the lenticles. It appears that this condition is characteristic of that variety, but in that year the markings were especially conspicuous. Microscopic examination of tangential sections of the skin at those points showed the presence of a fungus arranged along the edges of the cracks. The result of this examination prompted further investigation, and tangential sections of the skins of a large number of russeted and cracked apples of many different varieties, sprayed and unsprayed, were prepared. In every case a fungus, forming a dark layer around the edges of the cracks, was present on the surface of the skin. Its general appearance, as seen on all the fruits examined, was characterized by the presence of coarse, dark, septate, sparsely-branched mycelium, together with isolated groups of one-, two-, three- or four-celled " spores." The arrangement and appearance of these suggested that they were chlamydospores in origin. The three- and four-celled spores bore a striking resemblance to minute " packets." It was also observed that if the portions of skin were allowed to remain in contact with distilled water on a glass slide, innumerable oval, hyaline, non-septate spores were budded off from the mycelium and from the isolated chlamydospores. The presence of the dark, packet-shaped spores indicated that the fungus must be referred to the form-genus *Coniothecium* and it was found to conform with descriptions of *C. chomatosporum*.

Pole-Evans (14) and Van der Bijl (1, 2) both record a russeting disease of apple fruits and blistering of the twigs in South Africa, caused by *Coniothecium chomatosporum* Corda. Cunningham (5) reports a similar disease caused by the same fungus in New Zealand. A number of other workers also record this fungus as causing disease symptoms closely corresponding to the above.

Certain illustrations appearing in some of these published works depict apples bearing bands of russet markings which appear to correspond to those caused by frost. These " bands " often result in localized constriction of the growth of the fruits, imparting a " belted " effect to them. Although a fungus very similar to *Coniothecium* can generally be found on the surface of such blemishes, it is very doubtful whether it is the primary cause of them. Such markings, in contrast to those discussed at the beginning of the paper, are generally recognized in this country as being due to spring frosts occurring just before or during blossoming. No doubt has existed in the writer's mind that these russet bands on fruits are of quite different origin from the blemishes illustrated in Fig. 1. This shows a fruit of the apple variety St. Cecilia bearing what are at present tentatively considered to be typical symptoms of *Coniothecium* attack. This variety is grown on cordon trees at East Malling, and it is not uncommon to find fruits similar to the one illustrated, where the russeting and cracking occur most plentifully at the stalk end. It will be observed that the cracks afford points of entry for fruit-rotting organisms. Cox's Orange Pippin fruits also show the symptoms well (see Fig. 2).

Fruits showing blemishes caused by Capsid and by Apple Sawfly have been examined, and a fungus resembling *Coniothecium* has invariably been found on the blemished portions of skin. Furthermore, fruits known to have been damaged primarily by applications of Bordeaux mixture have always borne such a fungus. It thus appears to be highly probable that this fungus is a facultative parasite which, finding a roughened surface on the skin of a fruit a suitable settling place, can, under favourable conditions, assume a parasitic habit and so become of economic importance.

It is not forgotten in this connection that certain varieties of apples, such as those included in the " Russet " group (for example, Egremont Russet) are " naturally " russeted ; that is, the russeting is a varietal or constitutional characteristic, and is not in any way the result of a pathological condition of the fruits. A fungus of the *Coniothecium* type has been found on such fruits !

The present problem thus becomes a complicated one. Pathological symptoms identical with each other may, on apple fruits, be caused by spray damage, by weather conditions, or possibly by an attack of *Coniothecium chomatosporum* Corda. Work is planned to ascertain to what extent the fungus is pathogenic, so that it may be possible to distinguish damage caused by the fungus from that due to other causes.

The apple varieties Cox's Orange Pippin and Stirling Castle were used in the writer's experiments on the control of Apple Scab and Apple Mildew. From the outset, " pustules " or " blisters " were observed on the bark of the latter variety, and repeated efforts to show their connection with Apple Scab were unsuccessful. In no case could the presence of a fungus be detected by the

normal method of cutting and staining transverse sections through the blisters. When the fruit-russeting problem was being investigated, however, it was apparent from the papers on the subject that *Coniothecium* had several times been recorded as the cause of a branch-blister disease.*

Tangential sections of the bark covering the blisters showed the presence on the surface of a fungus similar to that found on russeted fruits. This fact has more recently been confirmed by the examination of numerous examples of identical blistering of the bark of other varieties. The blisters are characteristically purplish in colour, small, but conspicuous because of their bullate appearance. They are often found in dense masses partially or completely encircling the branches, but predominating on the side facing the prevailing wind, a fact which may hold some significance regarding the disseminating of the fungus. Fig. 3 illustrates a three-years-old branch of Cox's Orange Pippin showing typical blistering of the bark. The darker colour of the blisters can plainly be seen. Mr. G. H. Cunningham, while on a visit to East Malling recently, expressed the opinion that the symptoms on the fruit and twigs as illustrated by the photographs (Figs. 1, 2, 3) are identical with those he has observed in New Zealand, where *Coniothecium chomatosporum* Corda (5) is mentioned as the causal organism. He also considered that the fungus shown in tangential sections of apple skin and bark was identical with that found in New Zealand.

Pure cultures of the fungus have been obtained from russeted apple fruits and from blistered apple twigs, and these will be compared in detail with a type culture of *Coniothecium chomatosporum* from the "Centraalbureau voor Schimmelcultures te Baarn."

Symptoms similar microscopically and in general appearance to those described in apple have been observed on a number of other fruits, and pure cultures have been made of fungi associated with blemishes on pear (russeting), quince (cracking), plum (russeting), orange (russeting), walnut husk (russeting and cracking).

It will be noted that caution has been exercised in stating that the fungi observed in connection with differing pathological symptoms are superficially *similar* to *Coniothecium*, but they are not necessarily identical with that organism. Such caution is rendered essential by the statements of Martin (10) and of Neger (13), for they show that many fungi exist which are themselves very similar to *Coniothecium* or which produce developmental phases very closely resembling it. Such fungi may become associated with russeting and blistering symptoms quite accidentally, and may have no pathological significance whatever.

Work is in progress in an endeavour to identify by cultural methods the fungus which constantly occurs with the disease symptoms described, and to

* See *Van der Bijl* (1); *Cunningham* (5); *Massee* (11); *Pole-Evans* (14).

delimit it definitely from associated fungi which, perhaps in certain stages only, bear any resemblance to it. In this connection observations will be specially directed to the production, possibly, of some other stage in its life cycle. Cunningham (5), Van der Bijl (2) and Massee (11) have all recorded the ultimate production of a *Phoma* stage in *Coniothecium* cultures. Furthermore, Massee (11) considered that the ascigerous stage of the fungus is *Diaporthe ambigua* Nits., although no corroboration of that statement has so far been noted in the results of other workers. Guéguen (7) came to the conclusion that *Coniothecium*, and in particular *Coniothecium Amentacearum* Cda., must be considered an imperfect form of a genus related to *Capnodium*.

In the present study, a species of *Phoma* has been obtained on blistered twigs of Cox's Orange Pippin apple, together with a fungus of the *Coniothecium* type. Up to the present, no relation has been established in pure culture between the two forms. On the other hand, none of the pure cultures of fungi of the *Coniothecium* type has so far definitely given rise to any other recognized generic form.

Preliminary inoculation experiments were carried out in the spring of 1930 using suspensions of bud spores obtained from pure cultures of the fungi isolated from russeted apple fruits and blistered twigs, but they failed to give any conclusive results.

Certain data obtained in spraying trials for the control of Apple Scab on Cox's Orange Pippin indicate that there was less fruit russeting on trees treated with lime-sulphur in the summer than there was on similar control trees. This circumstantial evidence suggests that the damage was caused by an organism, the activity of which had been checked by the applications of this spray. Further support for this suggestion is afforded by the reaction of trees " worked " on different rootstocks, for " controls " on stock No. IX showed much more fruit russeting than did those on any other rootstock. The variety of rootstock on which a tree is " worked " has already been shown to influence the degree of susceptibility of that tree to Apple Scab and Apple Mildew (12).

Measures of control so far advised by other workers appear to favour manuring and severe pruning to induce the production of vigorous growth rather than spraying to prevent the incidence of the disease, for spraying has not generally proved satisfactory. Certain workers, notably Campbell (3), Cunningham (5), Carne (4) and Goodwin (6), are convinced that the appearance of the disease is only secondary to a weak and ill-nourished condition of the trees, and that measures resulting in the promotion of vigour must necessarily be of primary importance as a remedy. On the other hand, Pole-Evans (14) states that the disease can readily be stamped out by spraying with Bordeaux mixture, an operation which, at East Malling, has been found to increase the amount of fruit russeting (by spray damage) on certain varieties !

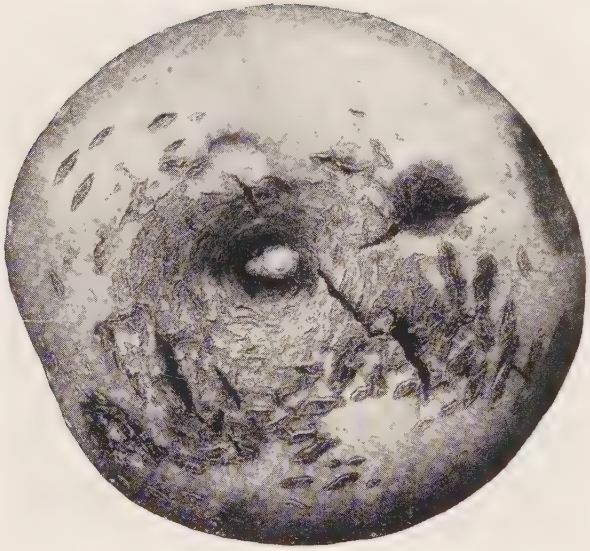


FIG. 1.
"Fruit-russeting" and cracking on St. Cecilia apple.

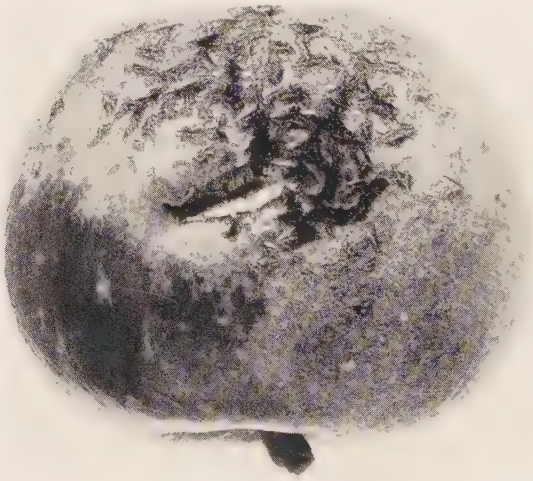


FIG 2.
"Fruit-russeting" and cracking on Cox's Orange Pippin apple.

FIG. 3.
"Branch-blister" on Cox's Orange Pippin.

Summary.

The occurrence is noted of a fungus, believed to be *Coniothecium chomatosporum* Corda, in association with cracking and russeting of apple fruits and blistering of the twigs. These symptoms are discussed and compared with those usually regarded as being due to the effect of weather conditions, especially frost, and to the damage caused by some sprays, particularly Bordeaux mixture.

The existence of other fungi, themselves very similar to *Coniothecium*, and of those giving rise to developmental phases similar to *Coniothecium*, complicates the investigations. Pathogenicity of the organism has not yet been proved by inoculation.

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THE EFFECT OF METEOROLOGICAL CONDITIONS ON APPLE SCAB, WITH SPECIAL REFERENCE TO THE CONTROL OF THE DISEASE.*

By M. H. MOORE.

" No observant individual who watches the incidence of plant diseases can avoid noticing the marked influence of one group of factors included in what is loosely termed the weather on the prevalence of many of these diseases. Apple scab is one of them, and potato blight is another."

With these words, an editorial in a recent number of the *Fruit Grower* (7) introduced the subject of forecasting outbreaks of potato blight (*Phytophthora infestans*) based on the previous occurrence of a certain combination of weather conditions, a matter which has recently been given much attention in Holland by Van Everdingen.†

A detailed study, during four consecutive and widely variable seasons, of the incidence and control of apple scab at East Malling (23, 24) affords very definite evidence of the truth of the above statement.

It must be admitted that the seasonal effect is only one of the factors studied at East Malling as influencing the occurrence of the disease. It would appear to be desirable, therefore, to review some of the work of those who have observed in much more detail the effect of meteorological conditions on the fungus as well as on the disease it causes, prior to the presentation of data collected more or less incidentally.

In making a survey of some of the numerous papers written about apple scab, one of the most noteworthy features encountered is the large number of writers who emphasize the importance of the effect of weather conditions on the incidence and control of the disease, and on the relative susceptibility of apple varieties.

Many experimenters have followed some definite line of detailed research into the effect of one or more factors, such as temperature and humidity, on the ripening of the perithecia and the discharge of ascospores, while others have incidentally observed the effect of the " group of factors loosely termed the weather " on the results they have obtained from season to season in investigating control measures. The observations made at East Malling fall into this latter category.

* This paper was read on September 26th, 1930, before the Conference of Observers under the Ministry of Agriculture and Fisheries' Agricultural Meteorological Scheme.

† *Tijdschr. over Plantenziekten*, 1926, **32.** 129-140.

The subject falls conveniently into three main sections: the effect of meteorological conditions (a) on the fungus itself; (b) on the reaction of the fungus to its host; and (c) on the application of control measures, particularly spraying.

(a) Effect on the Fungus (*Venturia inaequalis*).

This effect has not been studied in detail at East Malling but observations have been made by a number of workers in America. Their results will be utilized in illustration of the point under discussion.

Development of perithecia.

Keitt and Jones (19) in the United States have made very careful "seasonal development records" of the host, of the fungus and of the disease, while the meteorological records made have included relative humidity and air temperature, rainfall, wind velocity and hours of bright sunshine.

These authors state:—

"In moist chambers in dark compartments (Altmann apparatus), the perithecia matured comparatively slowly at 4° and 7° C. The rapidity of development was successively increased at 12°, 16° and 20° C. At 24° C. only occasional asci reached maturity. The optimal temperature for rapidity of development in the later maturation stages of the ascocarps appears, therefore, to be near 20° C. At 16° C. and relative humidity of 78 per cent., in one of the chambers used in the infection studies, the maturation of perithecia was checked until the leaves were thoroughly wet. Discontinuous wetting led to more rapid maturation than continuous wetting. These results agree with field observations at Madison in 1917, 1919 and 1924, when the development of perithecia was definitely checked by dry weather in early spring."

Berkeley (4) reports a study of perithecial development in *Venturia inaequalis* by G. C. Chamberlain. McIntosh apple leaves bearing scab lesions were gathered on October 15th and November 15th (1926) respectively, the latter date approximating to the normal time of leaf-fall for that year. The leaves were held at various temperatures in controlled incubators, and on the first day of each month from January to April, 1927, material was prepared for sectioning. From the data obtained by these methods, it is evident that perithecial development in *V. inaequalis* occurs at various temperatures, viz., 3°, 6°, 9°, 12° and 20° C. A larger number of perithecia developed in the group of leaves gathered on November 15th than in the samples collected a month earlier. The most advanced stage of development was observed in material held at 3° C. and examined on February 1st, when out of 282 perithecia sectioned, 15 were found containing mature ascospores and 39 with the asci formed. No further mature asci were found except one on April 1st, when observations ceased.

A number of interesting observations on the development of the perithecial stage of the apple scab fungus were made by Wilson (40). He states that

"delay in the time of leaf-fall is accompanied by delay in the time the ascospores reach maturity in the following spring. This delay of maturation of ascospores is not, however, commensurate with the delay in leaf-fall."

He suggests that the time of leaf-fall may be influenced by temperature and moisture in the autumn.

" In some instances the first frost that is sufficient to kill the leaves may lead to a retention of the foliage, while in others it may hasten defoliation."

" The optimum temperature for initiation and early growth of perithecia in oatmeal agar, agar made from dead apple leaves and naturally infected dried leaves was near 13° C. On apple-peel and oatmeal agars, short exposures to temperatures near 0° C. appeared to stimulate perithecial initiation, while this was not noted when the fungus was grown on apple-leaf agars. Limited data strongly suggest that perithecia may be initiated at temperatures below 0° C. These data are, however, not conclusive. The optimum temperature for the maturation of ascospores appears to be near 20° C. Temperatures of 24° C. and above are detrimental to normal ascospore development if the leaves are moist. No deleterious effect was observed, however, when air-dry leaves were kept at temperatures above 24° C. for eight days. There appears to be a transition from a lower to a higher range of thermal requirement as the perithecia develop." " Perithecia were initiated as readily in leaves which were moist enough to be fully pliable as in leaves which were wet and more readily in leaves which were alternately wet and dry than in those which were continuously wet. On the other hand, when the leaves were moist enough to be fully pliable, the perithecia matured as rapidly as those in leaves which were alternately wet and dry. However, continuous moisture led to certain abnormalities in perithecial development." " When the moisture of the leaf fell below an undefined limit, perithecial development was sharply arrested."

Thus, the work of these investigators indicates that perithecia may be initiated at a low temperature, but that, for the later stages of development, the optimum temperature is near 20° C. The presence of adequate moisture is an essential to normal development.

Dissemination of Spores.

Keitt and Jones (19) report that

" under ordinary conditions, ascospores appear commonly to be discharged during the first sufficient rain period following their maturity, provided the ostiole is open. Consequently, if rain periods occur with ordinary frequency, most of the spores available for discharge will have been comparatively recently matured."

Such spores possess a high degree of viability. It was found that

" the number and duration of the individual discharge periods and the quantity of ascospores ejected were influenced greatly by the amount and distribution of rainfall."

In laboratory experiments, these writers have observed ascospore discharge to occur freely at temperatures ranging from $\frac{1}{2}$° to 32° C. No trials were made at temperatures outside of this range.

It is evident that, while temperature plays an important part in rapid development of the perithecia, adequate moisture is the chief essential for the discharge of ripe ascospores. Wetting by dew was not found to be sufficient. The occurrence of drought, even when the spores were ripe, checked their ejection.

It is generally recognized in the U.S.A. that ascospores are the chief cause of primary infection. When an ascospore has caused infection, however, it gives rise to the conidial, or *Fusicladium*, stage of the fungus, and this is able to continue development and further infection throughout the growing season

of the host. Keitt and Jones found that scab lesions produced an abundance of these summer spores under ordinary field or greenhouse conditions without rain or artificial watering. Frey and Keitt (12) showed that the conidia of *V. inaequalis* are not easily separated from their conidiophores when dry, but became readily detached in the presence of water. It is acknowledged that a number of conidia are dislodged by agitation of the leaves in wind, and by mechanical agencies such as rubbing and knocking, but this is thought to be of little importance compared with dissemination through the agency of moisture.

Wallace (37) states that from a fragment of a leaf 1 cm. square, 5,630 ascospores were discharged in 45 minutes. On this basis he computes that it is possible for 8,107,200,000 ascospores to be discharged for each large apple tree in 45 minutes in wet weather. These figures afford some idea of the immense numbers of ascospores likely to be present in the orchard air following a rainy period when the spores are ripe.

Jehle and Hunter (15) report that in 1926, two quantities of scabbed leaves were left in each of five orchards, one quantity being retained under natural conditions and the other sprinkled daily with tap water. It was found that discharge of ascospores always occurred earlier from the latter than from the former. The writers conclude that, up to a certain point, early maturation of ascospores is correlated with frequent applications of moisture.

Martin and Clarke (20) correlated the discharge of ascospores with rainfall and found it heaviest during or after rain.

Howitt and Evans (14) made observations for six years in a neglected orchard near the Agricultural College, Guelph, Ontario, and they show that the mean temperature of the winter months (especially January, February and March) has a marked influence on ascospore development and the primary discharge of spores in the spring. This factor has been found to be more important, under Ontario conditions, than the amount of precipitation from the first of April to the time of ascospore discharge, and also to be more closely related to the development and discharge of the ascospores than is the average temperature of the days in April and May preceding primary ascospore discharge. The ascospores were found to be capable of retaining their viability until August 8th and probably longer. Wind dissemination of conidia up to a distance of at least seventy-five feet was demonstrated.

Viability and Germination of Spores.

In regard to moisture relations, Keitt and Jones (19) showed by controlled experiments that ascospores of *V. inaequalis* could remain viable in a mature condition in the asci for a period of several weeks when spore ejection had been sharply checked by reduction in the moisture supply. In seven years' field

experience in Wisconsin, the writers found no occurrence of a drought of sufficient duration to limit the viability of mature ascospores in the asci.

" The longevity of ascospores after discharge varied considerably with their vitality at the time of discharge and the conditions to which they were subsequently exposed."

Commenting on the work of Aderhold (2), and of Wiltshire (41), Keitt and Jones write :

" Aderhold states that the spores of the apple and pear scab fungi germinate readily when exposed to brief periods of alternate wetting and drying, and that brief periods of drying stimulate the formation of appressoria by bringing the germ-tubes in close contact with a firm substratum. Results by Wiltshire and the present writers are in general conformity with those of Aderhold."

These writers all agree that liquid water is necessary for the germination of scab conidia, but Keitt and Jones state that there is considerable difficulty in precluding the presence of minute drops of liquid water when germination tests are being made at high humidities.

In regard to temperature relations, Ewert (7) showed that when conidia of pear scab and of apple scab, taken from diseased leaves, were subjected to three periods of freezing, each of six hours' duration at a temperature of 16° to 5° F., the viability of those of *V. pirina* was not reduced, while only an occasional spore of *V. inaequalis* germinated after the second freezing. It would seem from these experiments that apple scab conidia would probably be unable to survive winter frosts.

McAlpine (21) thought that the important source of infection in Victoria (Australia) was from conidia that had become entangled in the hairs or scales of the buds, and, remaining thus during the winter, had germinated in the following spring. At that time he had not found the perithecial stage of the fungus in Australia.

Keitt and Jones (19) remark :

" Numerous germination experiments have shown that conidia freshly produced in nature possess a high degree of viability."

A large percentage of apple scab conidia survived the winter of 1920-21. The scabbed leaves from which they were taken had been placed in a standard shelter for housing meteorological instruments, and spores from the leaves were taken periodically and placed in sterile distilled water on glass slides in moist chambers at temperatures near 20° C. The lowest temperature recorded by the Madison Station of the U.S. Weather Bureau was —10° F. on December 28th. During this winter, temperatures below 0° F. occurred only four times. The conidia which survived the winter were protected from wetting. The writers have not succeeded in finding viable conidia of *V. inaequalis* which had survived the winter under natural conditions.

According to Frey (11), optimum germination and growth of ascospores of

V. inaequalis occurred at 10°-18° C. Growth was less vigorous at higher temperatures. Keitt and Jones (19) found that

" germination occurred at temperatures ranging from less than 1° (after 24-36 hours at ½° C.) to 32° C. The optimal temperature for the elongation of germ-tubes under the condition of these experiments appeared to be in the range of 16°-22° C. Germination and germ-tube growth were quite vigorous from 11° to 22° C. Below 11° C., the development of germ-tubes was normal, but retarded. At 28° C. and above the germ-tubes were much retarded in development."

Similar thermal relations have been shown by germination tests of scab conidia.

This review of some of the relevant literature has been presented to indicate primarily the obvious importance of the presence of adequate moisture and suitable temperature for the normal development of the apple scab fungus. With this reminder of the sensitive reactions of the fungus to slight alterations in its immediate meteorological environment as a basis, the relationship existing in the field between the fungus and its host, and the influence brought to bear by weather conditions, can more comprehensively be considered.

(b) Effect on the Reaction of the Fungus to its Host.

This subject embraces consideration of the factors which lead up to the occurrence of epidemics of scab in certain seasons, and which probably account to some extent for the variable susceptibility shown by different varieties of apples in different seasons.

As is hinted in the quotation with which this paper opens, references to the effect of weather conditions on apple scab are very common indeed, not only in the published work of numerous research workers, but also in the conversation of apple growers throughout the fruit-growing areas. Growers are able to state confidently in a general way that the weather *has* an influence on the degree of scab infection ; for instance that the disease is more common in a wet season than it is in a dry one. But that statement goes hardly far enough. It seems that the important thing to consider is the period in the growing season of the trees when the weather has the greatest effect on the relationship existing between the fungus and its host. From the wealth of available information on this question, it is evident that the weather just before, during, and just after blossoming is of the greatest importance ; hence investigators of the incidence of apple scab refer to a wet season when the rainfall during April and May is heavy, whatever the conditions later in the season may be.

Thus Jones and Morse (18) state that in Vermont there was no appreciable loss from scab in 1903, when the early season was very dry and was followed by a rainy late season. The wet season of 1902, however, gave serious scab infection (17).

Schneiderhan (34) points out that May rainfall apparently determines to a high degree the intensity of infection for the season. He showed (35) that in

summer the spread of the disease was checked during drought, but was resumed when rain fell again.

Osmun (28) reports that an unusually warm and wet spring in Massachusetts in 1921 provided ideal conditions for the discharge and germination of the spores of the apple scab fungus, and resulted in a very severe outbreak of the disease. A second period of heavy rainfall in July was accompanied by considerable secondary scab infection.

Russell and Morrison (32), on the other hand, state that owing to the dry spring and summer of 1921, the incidence of scab in Wisconsin was very slight. These apparently contradictory results serve to show how the incidence of the disease may vary in the same year in different localities, according to the weather conditions in those localities.

Smith (36) speaks of 1892 as being an unusually bad year for scab in Western New York and South-West Michigan because of the wet spring.

Wallace (37) discusses the susceptibility of varieties of apples to scab and states that considerable variation is noted from season to season, i.e., a variety may be highly resistant in one season and susceptible in the next. The probability of a direct effect of different weather conditions on the constitution of the host should not be forgotten, and, while there is no satisfactory explanation of the phenomenon, Wallace suggests that it depends on whether greatest liability to infection happens to be just when the spores are being liberated in large numbers. The period of dissemination of spores has already been shown to depend very largely on meteorological conditions.

Aderhold (1, 3) concludes that varietal susceptibility varies in different localities. The results obtained from one, or even two seasons' investigations are practically devoid of value when considered individually. Wallace (37) writes :

" One can plainly see by examining his (Aderhold's) results that resistant varieties cannot be selected from the observations of a single season, even though that season be an epidemic one. This doubtless accounts for some of the conflicting reports on resistance of certain varieties to scab."

Wiltshire (41) notes that a variety may be badly attacked in one year and almost resistant in the next, even though the organism may be quite proximate. There seems to be a definite correlation between the age of the foliage and its powers of resistance. No conidia have ever been produced in his experiments from inoculations on mature leaves. Late infection is often seen on new growth produced late in the season, usually when heavy rains follow a summer drought.

Ward and Thomas (38) report that there was less scab infection in the 1918-19 season than in the previous few years. A review of the climatic conditions in the springs of 1916, 1917 and 1918 is given and comparisons are made. The worst infection in 1917-18 was in Northern districts and in 1916-17 in Southern districts of Tasmania. There was a marked all-round improvement

in 1918-19. These authors appear to be convinced that weather conditions play a most important part in the development of the disease.

Nicholls (27) states that scab is the cause of great losses in Tasmania in wet seasons. The incidence of the disease is localized according to climate. He has not been able to obtain a spore discharge in dry conditions under the microscope and thus assumes that moisture is essential. He thinks that this fact accounts to some extent for the vagaries of the disease. He hints that scab is never troublesome in hilly, exposed areas as the leaves are blown to the foot of the hills and carry infection away with them.

Putterill (31) concludes that the intensity of infection by scab depends on the climatic conditions in spring and early summer. Cool, moist weather is favourable to its development, while dry, windy weather checks it. The chief factors governing infection appear to be time of blossoming and of coming into leaf, and the occurrence of cool, wet weather at that period. Most varieties of apples appear to be susceptible, though relative susceptibility seems to vary considerably with the district in which the fruit is grown. Dry weather at blossoming time means difficult conditions for the ejection of spores and also for the germination of those ejected. Trees should be shaped to allow of good air circulation.

Van Poeteren (30),* discussing the conditions influencing the appearance of apple scab and pear scab in Holland, states that the weather is a very important factor. The disease is usually more severe in damp than in dry seasons, and that writer suggests the possibility of selecting varieties which are proof against the climate. A considerable difference in the susceptibility of varieties exists. In Holland, much fruit (especially pears) is grown that hails from a warmer climate, and these varieties appear also to be the most susceptible to the disease. Location probably plays its part also. It has been observed that trees in a low, damp, cold soil are most vigorously attacked by scab. An explanation, which is probable but has not been proved, has been suggested for this. It is assumed that in such a soil, growth is slower. The different organs (shoots, leaves, fruits) therefore remain longer in a state when they are most susceptible to attack by scab. In the late summer, moreover, the twigs do not fully ripen and therefore are attacked more easily in the following spring by liberated ascospores.

Wallace (37) concludes from data collected and presented in his paper

" that the leaves and buds of the apple are susceptible to infection as soon as they are exposed, but that infection does not occur until the ascospores have matured, or until the first appearance of weather conditions favourable for infection following the maturity of the ascospores. According to observations during the past three years, the spores do not reach maturity until the blossoms are either opening or just ready to open. It seems, therefore, that there is little danger of abundant infection earlier than about the time when the blossom buds show pink. It is to be noted that seasonal variations markedly influence the development

* The writer is grateful to Mr. W. C. Moore, Ministry of Agriculture Plant Pathological Laboratory, Harpenden, for translating this paper.

of the disease. In the case of abundant fall rains accompanied by fog, or the occurrence of excessive dew, a late infection of scab appears. The disease may not appear on infected fruit until the fruit is stored. This phenomenon has been called to the writer's attention recently by several investigators and growers."

A number of other writers [Brooks (5), Goethe (13), McAlpine (22), Morse (25)] have mentioned the importance of a wet period during or just before harvest time in the development of scab under ordinary storage conditions. Nicholls (27) found examples of the growth of scab in store, and attributes this to a dry autumn, when the growth of the fungus was hindered through lack of moisture. Ventilation is the only remedy. Morse and Lewis (26) report what appeared to be new infection in stored apples.

Wallace (37) thinks that

" heavy dews or light rains at this time would be more effective in inducing late fruit infection than washing rains, which would tend to keep the spores in motion over the smooth surface of the apple. At the time of the early infection the surface of the young fruit is sufficiently rough and hairy to furnish lodging-places for the spores."

As already stated, Keitt and Jones (19) found that scab ascospores and conidia germinated in sterile distilled water through a range of temperatures beginning at less than 1° and extending to 32° C., with an optimal rate of germ-tube elongation in the range of 16-22° C. The temperature relations of mycelial growth are very similar to those of germination of spores and elongation of germ-tubes. Observations indicate that the host has a distinctly higher temperature range than the scab fungus has. The thermal relations noted in the development of the disease agree closely with those of germination and growth of the parasite.

" The minimal periods of continuous wetting necessary for leaf infection by ascospores fall within the following limits for the temperatures listed : 6°, 13-18 hours ; 9°, 9-11 hours ; 15°, not more than 8.5 hours ; 20°, 4-6 hours ; 24°, 4-6 hours ; 26° C., 8-10 hours."

The writers think that most natural infections require somewhat longer periods of wetting than the minimal periods indicated above, for under natural conditions, less vigorous and less favourably placed spores would stand a better chance of causing infection given a period of wetting longer than the minimum. They agree with Aderhold (2) that discontinuous wetting favours infection. This is probably because the germ-tubes are brought into contact with the cuticle during the periods of non-wetting, and this stimulates the formation of appressoria, thus securing the fungus to the leaf and aiding the production of infection hyphæ.

Variations in humidity, in a limited number of experiments, do not appear to have exerted any significant influence upon the development of the disease. Exposures of the spores to full sunlight during the dry intervals in discontinuous wetting did not preclude infection on those leaves which had not become resistant when the plant was returned to the moist chamber.

In discussing the critical periods for the development and control of epidemics, Keitt and Jones (19) state that under Wisconsin conditions

" the most critical period extends from the time the apical parts of the sepals are first exposed in the opening fruit buds to an indefinite time some two to four weeks after petal-fall. In cool summer climates, as at Sturgeon Bay, Wisconsin, if there has been sufficient primary infection to lead to the development of an abundant secondary inoculum, important infection periods may occur at any time prior to harvest. Hot, dry weather, however, sharply checks scab development. A second critical period for scab development occurs in the fall, when cooler weather and sufficient moisture may lead to an important late infection of fruit and to the more abundant establishment of the fungus on the foliage, particularly on the younger leaves of late terminal growth and on the lower (dorsal) surfaces."

The detailed observations of Keitt and Jones alone show how intimately apple scab is dependent on meteorological conditions such as temperature and moisture for its development as a fungus and its initiation and progress as a disease. The most noteworthy points are, that the presence of moisture is an essential factor, and that the fungus and the disease develop best at a temperature of approximately 20° C.

Observations on the incidence of the disease on the young shoots, leaves and fruits of the apple variety Cox's Orange Pippin at East Malling during the past four years have revealed the reactions of the disease to contrasting seasonal conditions in a very definite manner. The data collected demonstrate that the critical period for primary infection extends from blossoming until the fruit is well set, and that the weather conditions during that period are all-important. A wave of secondary infection may be initiated in the late summer, if a dry spell is followed by a rainy period. Such infection usually confines itself to the younger leaves at the tips of the current year's growth and to small lesions on the fruit. These observations agree in general with those recorded by other workers and reviewed above.

The year 1927 afforded a striking illustration of the fact that the most critical period for scab development, and the stage at which the trees are most susceptible, is undoubtedly around flowering time. May of that year was unusually dry and sunny, and was followed by an extremely wet and sunless summer. It was generally thought that after weeks of rain the apple crop would be very scabby, but the fruits picked from the experimental spraying plot at East Malling (24) were surprisingly lightly scabbed. The variety under observation was Cox's Orange Pippin, which is generally accepted as one of our most scab-susceptible varieties. It would appear, however, that this was not the general experience in that year, for Pethybridge (29) writes :—

" The season of 1927 was distinguished by a remarkably dry May followed by a continuously wet, sunless summer. Hence such wet weather diseases as Potato Blight, Leaf Spot of Celery, Apple Scab and Downy Mildew of Hop were more than usually prevalent and destructive."

The 1928 season was noteworthy in that it provided remarkable contrast to the previous year. May was abnormally wet and was followed by fine, dry

weather in general until the latter part of July. Superficially, it was not a "scab year," but when the records of infection are examined they show that scab developed in almost epidemic intensity early in the season, with the result that the fruits of unsprayed trees were badly blemished by early infection. The lesions tended to dry up during the latter part of June and in July, but general resuscitation of the old spots was observed in August, following a break in the dry weather.

The year 1929 was different again. It was remarkable for one of the longest droughts for many years. Extremely dry and sunny weather prevailed from very early in the year to the end of the summer. According to preconceived notions, it was the ideal year for scab-free fruit. Records of infection on Bramley's Seedling and Worcester Pearmain fruits at East Malling (24) in that year show that there was an unusual quantity of badly scabbed fruit. The Cox's Orange Pippin fruits were severely blemished also. Careful observation throughout the season showed that

> "scab did not really get the upper hand early in the season, but developed slowly, though surely, on the control trees. Heavy dews on many occasions in 1929 were most probably responsible for the steady development of scab on unsprayed trees, in spite of the hot, sunny days. An examination of the meteorological data at East Malling for June and July, 1929, supports this explanation, for, on many occasions, the minimum night temperature was well below the dew point, while the trees were often laden with moisture early in the morning."

Figures for scab infection during 1930 are not yet analysed, but general observation of the fruits on Worcester Pearmain trees at East Malling indicated that the degree of infection was comparatively slight. As in 1927, May was fine and dry, and progress of the disease was undoubtedly checked then. The latter part of the summer was wet, and the influence of this was shown by the incidence of late infections on the fruits of Worcester Pearmain, Bramley's Seedling and certain other varieties. Osmun (28) records a similar instance. Such infection spots are characterized by their small size when compared with the earlier ones, and by the vigorous production of conidia. The leaves at the tips of the young shoots, especially of Bramley's Seedling and of Cox's Orange Pippin, showed this late infection to a much more marked degree than did the fruits. Experience tends to confirm the opinion that a stage is reached during the development of apple fruits after which they become much more resistant to scab than they were in an earlier stage of development. The increase in the degree of infection of the fruits following a wet period in late summer is not commensurate with that which results when a similar wet period occurs in May, although this cannot be entirely due to an absence of inoculum, as shown by the sooty appearance of the youngest leaves. The older leaves also appear to acquire a measure of resistance, as reported by Wiltshire (41), who emphasizes that immunity is not due to freedom from initial attack.

(c) Effect on the Application of Control Measures, Particularly Spraying.

As is well known, two standard fungicides, Bordeaux mixture and lime-sulphur, are in general use for the control of scab throughout apple-growing areas. The problems that arise in connection with the influence of the weather conditions are, in the main, two—which of the two sprays can be used with most beneficial results in a given set of weather conditions, and at what time can it best be applied to give the maximum desired effect? The latter question very naturally gives rise to a parallel thought: can weather forecasting be of any assistance in determining the best time to spray?

Spraying is the staple method at present in practice for the control of apple scab. The results of research work, reviewed above, suggest that general cultural practices can also be of assistance when used as adjuncts to spraying. Ploughing-in of the dead, scabbed leaves on the ground in the winter, pruning the trees to increase vigour and remove young shoots bearing the winter scab pustules, and feeding the trees by manuring to retain them in normal healthy growth, are some of the more obvious and generally-practised measures. Wallace (37), Eastham and Hunt (6), and Putterill (31), however, mention a point which seems to be of great importance also—that of keeping a good circulation of air among the trees so that they become dry more quickly after wet periods. This can be effected by efficient soil drainage and good shaping and thinning of the trees.

The problem of deciding which of the two standard fungicides to use, as depending on existing weather conditions, must be dismissed here very briefly. It is evident, on reading the theories put forward for the action of Bordeaux mixture alone (which are very clearly presented and reviewed by McCallan (39) in a recent publication) that this subject is itself a very wide one and cannot therefore be discussed here. Suffice it to say that Bordeaux mixture is usually considered more likely to damage the foliage and fruit of apple trees in cool, moist weather, and lime-sulphur is more harmful in hot, sunny weather, especially when the application is made under such conditions. In actual practice, the weather is not the only matter to be considered, and, assuming equal efficacy of the fungicides, the final decision usually rests with the pressure of economic conditions such as convenience, the presence or absence of other pests and diseases, and the varieties of fruit grown.

In regard to the time of application of sprays, various workers have discussed the relationship which this problem bears to the annual cycle of the fungus as influenced by local climatic conditions. Keitt and Jones (19) emphasize the importance of providing adequate protection of at least the blossom parts during the critical pre-blossom period, and for use under severe epidemic conditions in Wisconsin they tentatively recommend three applications of spray

before blossoming, the first in the " green-tip " stage ; the second in the " early closed-cluster " stage and the third just before the blossoms open, preferably in the " open-cluster " stage. These applications are usually followed by a number of post-blossom sprayings. The writers also discuss modifications of this suggested programme according to seasonal or local conditions.

Wallace (37) writes :—

" It is impossible to say what might happen in some cases, but it is certain that in the two cases mentioned above, the dormant spray did not materially reduce the amount of scab. The methods that are most likely to be successful must be adopted. A method that has failed during two consecutive years is certainly not to be relied on. It should be understood that good results may be obtained for many seasons or under certain conditions when the application before the opening of the blossoms is omitted. In many cases a single spraying after the blossoms have fallen gives excellent results. The point to be emphasized is that in cases in which the early summer spraying is important, the dormant spray cannot be substituted for it."

Wallace then stresses the importance of making each application at the proper time and of being prepared to do so, and continues :—

" The rule for every grower, therefore, should be to provide sufficient spraying equipment to spray his entire orchard thoroughly within four or five days at the most. This is much more important than is generally supposed, since the spray may entirely fail to control scab if delayed one or two days too long, thus permitting the infection to occur before the application is made."

Salmon and Ware (33) state :—

" The attention of the fruit grower needs to be drawn to the fact that with certain varieties, a severe infestation of scab may occur on the leaves before the blossoms open. It appears quite certain that a ' pre-blossom ' spraying is as necessary here in order to protect certain varieties of apples from scab as it is in Canada and the United States, where such early applications are becoming an established routine operation. The very unsettled weather conditions which often prevail in England at the end of April and beginning of May undoubtedly make spraying at that time of the year an operation very difficult to carry out satisfactorily. It must be remembered, however, that it is the same weather conditions (viz. frequent showers or mists when apple leaves are wetted and remain so for some time) which make spraying difficult, which also provide the optimum conditions for heavy scab infections to take place."

Jehle (16) reports that the maximum ascospore discharge of the scab fungus occurred prior to the " pink-bud " stage in the Eastern Shore region of Maryland during the years 1926 to 1929, this being noted in the Western Shore region also in two of these years. In 1927 and 1929, when maximum ascospore discharge occurred while the trees were in bloom in Western Maryland, a few warm days developed fruit-buds so rapidly that orchards not sprayed earlier than the "pink-bud" stage could not be covered before they were in bloom. Variation in the periods of ascospore discharge in relation to the stage of development of the host is due to the fact that the fungus develops most rapidly at about 40-65° F., whereas apple trees develop most rapidly at higher temperatures. Experience indicates that, as a rule, it is unsafe for Maryland growers to wait until the " pink-bud " stage before making their second spray application ; in some years the application given at the " delayed-dormant " stage may be the most

important for the control of scab, as it usually protects the trees from the earliest ripening spores.

A special study has been made at East Malling (24) of the relative importance of the time of application of sprays. Dead scabbed leaves have been collected for the past three years and kept under natural conditions throughout the winter. Observations have shown that the ascospores normally ripen just before apple trees are in bloom, and continue to be discharged, given favourable weather, from that time until the petals have fallen at least, and sometimes over a longer period, depending on the weather conditions. Viable conidia have been found in scab pustules on the young shoots of apple trees as early as the middle of January, although the main supply of inoculum from this source is not normally produced until several weeks later. Dormant applications of strong fungicides were almost or entirely useless, for fresh crops of conidia were produced in pustules which opened subsequent to the application of spray.

The supreme importance of the " pink-bud " application is one of the main results obtained in the East Malling scab-spraying trials with the apple variety Cox's Orange Pippin. Certain trees received one application only, at the " pink-bud " stage ; others were sprayed twice, post-blossom only, the first application being given at petal-fall and the second about three weeks afterwards, while others had three applications, one at each of the above three periods. There were control trees for each experiment.

Three applications gave the best results in each of the four years, and in spite of the early dispersal of spores noted above, an application of spray prior to that at the " pink-bud " stage has not been found necessary. Two applications, post-blossom, gave, in some cases, no better results than one only, pre-blossom. This may be due in some measure to the fact that post-blossom sprays were of necessity more dilute than pre-blossom ones, yet the beneficial effect of the pre-blossom application was always shown where it was applied as well, thus indicating that the *time* of application was of great importance. The pre-blossom spray by itself afforded protection from infection for a considerable period when the weather at blossoming time was favourable for scab development. Where this application was omitted, scab infection obtained the upper hand early in the season, and post-blossom sprays were thus applied too late to hold the progress of disease completely in check.

An exception was shown in 1927. As previously stated, the blossoming period in that year was fine and dry, and infection did not develop early. Lack of primary infection was demonstrated in the data obtained at the end of the season, for, although subsequently the summer was extremely wet, none of the trees included in the spraying experiment was very heavily scabbed. Thus the effect of spraying in that year was not so pronounced as in other years, and this applies more particularly to the one, pre-blossom, application. Spraying,

especially the pre-blossom application, showed to great advantage in the following year, however, when May was wet and infection attained almost epidemic severity early in the season.

The season of 1929 has already been the subject of comment. Although unsprayed trees were heavily infected at the end of the season, those that were sprayed were well protected, whether the application was given before blossoming only, after blossoming only, or before and after blossoming. The data indicate that at no particular period was scab infection really severe, but that it developed slowly all through the season. The results of spraying in 1930 are not yet available.

Folsom (10) makes an interesting comment. He writes that several years' spraying tests are necessary for reliable conclusions owing to the effect of seasonal variation. If it were known what natural conditions cause these variations, it might be possible to adapt the spraying programme to the needs of the season. He appears to be hinting at weather forecasting, and suitable spraying based on the knowledge of the reactions of the disease to different weather conditions.

Young and May (42) carried out experiments to determine when sprays should be applied for maximum efficiency under Ohio conditions. They state that infection can take place readily at any time after the buds begin to open, depending only on the supply of ascospores present in the orchard, sufficient air moisture and a suitable temperature. They showed that sprays are most effective when applied just previous to a rainy period which leads to intensive discharge of ascospores from fallen leaves. A method was devised to allow of predicting such periods, which, in conjunction with a regular weather forecasting service, yielded excellent control results in 1926 at numerous points in Ohio. It was found that the sprays gave protection over a comparatively short period, and should be repeated before each intensive discharge of ascospores. The subject of forecasting outbreaks of diseases was admirably dealt with by Foister (9) in a paper to the Agricultural Section of the Conference of Empire Meteorologists in 1929. That author discussed the possibilities of implementing such a scheme, together with some of the difficulties to be overcome in acquiring and correlating the necessary data.

In America and other countries, spraying based on a weather forecasting service may prove a great boon and a workable proposition, but as far as this country is concerned, it would not at present appear to provide a satisfactory solution of the scab-control problem. It seems that by far the best thing the grower can do is to spray in the " pink-bud " stage and at petal-fall *every year* as a routine measure. He will be guided by his special knowledge of his own particular district as to the advisability of making an application prior to the " pink-bud " stage. In certain seasons he might find that his neighbour had

fared as well by not making a " pink-bud " application, but it can be asserted from past experience that these occasions in most localities are comparatively rare. Exceptional cases may be provided in districts where the climatic conditions are such that the appearance of scab before or during blossoming is unusual. It is considered at East Malling that the " pink-bud " application for scab is all-important, and should never be omitted on susceptible varieties. It safeguards the grower for the blossoming period when he should not spray the trees, and when scab could therefore appear in epidemic intensity. It seems to be in the matter of later post-blossom applications where the grower wants guidance, for the appearance of later infections is closely related to the type of season. It may be said it has been shown that early infections are also seasonal, but they are the rule rather than the exception, and are of vital importance. The important practical point to be borne in mind is that there are so many other necessary operations to be attended to on the farm during the summer that the average grower will not be " bothered " with spraying at that time if it is not evidently necessary. How is he to know when it is necessary ? It seems that here is a promising field for foretelling outbreaks and issuing spray warnings, but one is always in conflict with the local conditions, which are evidently of great importance. The forecasting service could do a great deal in a general way, but the problem presented in localized areas appears to be beset with difficulties.

The detailed researches of Keitt and Jones and of other investigators show most clearly how faithful is the response of the fungus to fluctuations in its immediate environment. If, then, meteorology is to be of assistance, will it not mean the making of an enormous number of observations all over the country in order to attempt to foretell the imminence of sudden waves of local infection ?

The thought that immediately presents itself is the possibility of stimulating the grower to be his own observer. This method would naturally present certain difficulties, but if he is sufficiently keen to want to see his crops free from scab blemishes, he will also readily be receptive of any help given to enable him to decide for himself whether further, later sprayings are necessary in his particular case. So much will depend on *the condition of his trees* that it seems the problem must eventually be one for the individual to decide. It is not suggested that the grower need be a skilled meteorologist, but periodic inspection of his trees for the first signs of the development of scab, aided by any forthcoming knowledge (which he should make a point of acquiring) of the conditions likely to lead to an attack, and by the advice, if required, of the local advisory officer, appears to be a possible method of approach. The fact that the scab fungus normally has rather a long incubation period is a matter for satisfaction in this connection.

If, on the other hand, the weather forecasting service should state that wet conditions will prevail and be prolonged generally over a certain large area at a given time during the summer, such information could be taken as a fairly reliable indication that an outbreak of late scab infection would make its appearance in that area, and apple growers would be well advised to make a further application of spray, or possibly of dust, to guard against it.

There is one other point which must not be forgotten. The prolonged drought in 1929 clearly showed that the so-called " dry " season may not be a dry season at all so far as scab is concerned. Very heavy dews in that year enabled the disease to persist during the latter part of the summer, with the result that 1929 was a bad scab year for certain apple varieties, at any rate at East Malling, in spite of the drought. This provides an example of the type of information with which the grower should be equipped.

One can scarcely avoid coming to the conclusion, on weighing the " pros and cons " of a weather and spraying advisory service in connection with scab control, that, to be of greatest use to individuals, it would be difficult of accomplishment except in a very general way, in our present state of knowledge, while the " insurance method "—that of regarding at least the " pink-bud " and petal-fall applications as a routine measure to be supplemented by later sprayings where such are deemed necessary—would appear to provide the solution to most of the difficulties. The complaint of a certain type of grower—perhaps, in a way, a very natural one—that he has " too much else to do " is always met with. One can imagine, however, a similar remark being made in the event of an urgent spray warning, and it can be assumed that the spraying would not be done in any case. A lively appreciation of the fact that great care must be taken to control scab if high-class apples are to be grown is one of the first essentials that must be impressed on the present-day fruit grower.

In four varied seasons at East Malling, very good scab control was obtained in each case by following a rigid, annual, three-applications programme on a very susceptible variety, Cox's Orange Pippin, and, although it cannot definitely be claimed that in each of the four years every one of the applications was essential, the available evidence suggests the inadvisability of omitting any of them.

Summary.

Meteorological conditions are discussed in their effect on :—

(a) *The apple scab fungus*—being chiefly a review of published work dealing with laboratory experiments on the development of perithecia and the viability and germination of spores, and with field observations on the dissemination of spores, aspects which have not been studied in detail at East Malling.

(b) *The reaction of the fungus to its host*—reviewing seasonal variation in susceptibility of the host, and the conditions governing the appearance of scab epidemics.

(c) *The application of control measures, particularly spraying*—including a discussion on the practical value of a spraying advisory service based on forecasts of the weather in its relation to the appearance of this disease.

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THE PRESENT DISTRIBUTION OF THE BROWN ROT FUNGI: ITS ECONOMIC SIGNIFICANCE.*

By H. WORMALD.

From time to time the attention of fruit growers has been drawn to the ravages caused by the different species of Brown Rot fungi. The most familiar symptom of infection induced by these parasites is the rotting of fruit; the affected parts turn brown and, usually within a few days, the fructifications of the fungi appear on the surface as pustular outgrowths, which the microscope shows to be dense tufts of branched hairs, bearing chains of spores—a type of fungal fructification known as *Monilia*. Other fruit-rotting fungi, it is true, may cause discoloration of the infected tissues, but infection by the parasites under consideration is so general on ripening fruit that the term "Brown Rot" is usually restricted to the destruction caused by these fungi (*Monilia*). Under certain conditions, a second type of fructification, in the form of a stalked cup, develops from the infected, mummified fruit. The production of this higher or "perfect" form of fructification shows that these fungi belong to the genus *Sclerotinia*, but the name *Monilia*, which is descriptive of the more common reproductive phase of the fungi, is still sometimes used. Although rotting of the fruit is, perhaps, the best known form of damage caused by these fungi, yet one of them produces other types of disease which have been referred to as Blossom Wilt, Brown Rot Canker, Wither Tip and Shoot Wilt, respectively.

Whilst studying the Brown Rot fungi, and the different forms of damage caused by them on fruit trees in this country, the writer has collected specimens and cultures of Brown Rot organisms from the various fruit-growing countries of the world in order that the forms occurring here could be compared with those found abroad. The results have revealed certain facts relative to the distribution of these fungi, which are not without interest from a practical point of view.

Brown Rot diseases are to be found in all the chief fruit-growing countries where the species of Pyrus and Prunus are cultivated, but the fruit-rotting Sclerotinias attacking these crops are not the same in all regions; and, since the bionomics and mode of parasitism vary with each parasite, a knowledge of the distribution of these parasites is desirable, so that the necessary precautions may be taken to prevent the introduction of any one of them into a country in which it has not at present been found.

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As the chief types of disease caused by the Brown Rot fungi in this country have already been described in earlier papers it will not be necessary to give a detailed account of them in the present article ; but a brief review of the principal facts relating to the diseases is essential to make clear the importance of a knowledge of the distribution of the organisms concerned.

Species of Brown Rot Fungi.

In the British Isles there are two species of Brown Rot fungi that, together, are responsible for considerable loss in the fruit crops every year* ; they are known as *Sclerotinia* (*Monilia*) *fructigena* and *Sclerotinia* (*Monilia*) *cinerea*.

(1) *Sclerotinia fructigena* is the common fruit-rot fungus of apples, pears and quinces, on which it produces conspicuous yellowish pustules of the Monilia type, often arranged in concentric circles round the point of infection. As already pointed out in previous articles, this fungus causes infection through the fruit alone, although it sometimes passes from the fruit itself into the fruiting spurs and even into the branches, causing cankers. It is particularly destructive as the fruit approaches maturity. The infected fruit often falls to the ground, and it is not uncommon in certain seasons to see the ground under apple and pear trees strewn with fruit in various stages of decay, bearing numerous pustules from which myriads of spores arise. This particular fungus is only too familiar to growers in this country ; but, as it is unknown in certain fruit-growing regions abroad, the accompanying illustrations (Figs. 1, 2, 3 and 4) are presented to enable overseas readers of this *Journal* to recognize the parasite, and to show how prolific it is in pustule and, consequently, in spore production.

It has recently been shown† that *S. fructigena* may infect apples at the time of picking, if the fruits receive injuries such as may obtain when they are picked *from* their stalks instead of *with* their stalks. Further, core-rot, with premature fruit-fall, of White Transparent apples, has been found to be associated with infection by the same fungus.‡ It is also responsible for considerable loss in the early stages of storage of apples, the fruits often turning black in the store.

The perfect, or *Sclerotinia*, stage of this fungus develops from infected, mummified fruit which has fallen to the ground. As compared with the *Monilia* stage, it is very rarely met with anywhere, and it has not yet been found in this country. The fungus, however, can persist without the intervention of this perfect stage. Some of the infected fruits shrivel up and remain on the trees as "mummies" through the winter. The parasite remains quiescent in these

* Two other species of *Sclerotinia*, attacking the leaves of the Medlar and the Quince, respectively, have been recorded for this country, but these fungi are of minor importance economically.

† *Journ. Min. Agric.*, Vol. XXXIV, September, 1927, p. 552.

‡ Dowson, W. J. On a Core-Rot and Premature Fall of Apples associated with *Sclerotinia fructigena*. *Trans. Brit. Mycol. Soc.*, Vol. XI, 1926, pp. 155-161.

mummies until early in the following summer, when it produces a new crop of spores of the Monilia type ready to infect the growing fruit.

It has also been observed that the fungus produces Monilia pustules on infected spurs, and cankers, and that these fructifications, too, resuscitate and give rise to new crops of spores in early summer. As soon as the growing fruit becomes infected from these over-wintered sources of infection, the fungus quickly re-establishes itself and, under favourable conditions, is rapidly disseminated.

Judging from the reports of investigators on the Continent of Europe, it appears, generally, to have been assumed that *S. fructigena* is almost confined to core-fruits, such as apples and pears, but observations in this country have shown that it causes, in some years, considerable wastage in the plum crop; of other stone fruits, it also infects cherries and peaches.

The destructive nature of this fungus, in relation to the actual fruit crop, is emphasized here because this particular parasite, which is the principal rot-producing fungus of the apples in this country and on the Continent of Europe, is unknown in some of the chief fruit-growing regions in other parts of the world where apples are grown on a large scale.

(2) *Sclerotinia cinerea*, the second of the two principal fungi mentioned, is almost confined to stone fruits. On plums and cherries, it causes a brown rot similar to that produced by *S. fructigena*, but the fungal pustules which appear on the infected fruit are smaller and grey, not yellow, in colour. Although fruit-rot, caused by *S. cinerea*, may at times be severe on plums and cherries, the chief importance of this fungus lies in the fact that it infects the flowers, causing Blossom Wilt; from the flowers it passes into the spurs and, frequently, into the branches, killing them back. Thus, Morello cherry trees are often severely crippled by its attacks. On sweet cherries, although infection of the flowers is sometimes alarming, actual killing back of branches is not common; but some varieties of plums lose many young branches following Blossom Wilt. It also infects the young, green shoots of plums and cherries, producing the condition known as Wither Tip.

A fungus, which is indistinguishable microscopically from *S. cinerea*, as found on plums and cherries, infects the flowers of apple trees, some varieties, such as Lord Derby and James Grieve, being particularly susceptible. This fungus, known as *Sclerotinia cinerea* forma *mali*, often extends into the branches, forming cankers which girdle and kill them.

(3) Another Brown Rot fungus, which is rife and very destructive in certain parts of the world, does not occur in this country. It is prevalent in North America, and has been named *Sclerotinia americana*.* Microscopically,

* The nomenclature of the common Brown Rot fungus of America is in dispute. At present, the writer prefers the name *S. americana*, although certain American writers maintain that *S. fructicola* has a prior claim.

and in the general appearance of its Monilia fructifications, it is similar to *S. cinerea*. That this fungus can be distinguished by laboratory cultural methods from *S. cinerea*, was first pointed out by the writer in 1917. This has not only been confirmed by American investigators, but evidence is accumulating to show that the two differ in their mode of parasitism. Recently it has been shown that *S. cinerea* also occurs in North America, and it has been possible to compare the two with regard to their parasitism. The consensus of opinion, among American workers who have studied the subject recently, is that *S. americana* is chiefly a fruit-rotting fungus, but that it may also attack flowers and cause cankers, whilst the chief damage caused by *S. cinerea* is infection of the flowers and production of Blossom Wilt. For example, Professor Barss, who has studied the two side by side in Oregon, writes: "It is this ordinary Brown Rot fungus*that causes the severe attacks of fruit-rot of stone fruits in Oregon. It often causes blossom blight as well. There is, in addition, a closely-related fungus,† common on the Pacific Coast, which often causes very severe attacks of blossom and spur blight and twig cankers on all kinds of stone fruits and on certain varieties of pears, but which causes little rotting of fruit." Another difference between these two fungi is associated with the development of the perfect stage on the fallen, mummified fruit. *S. americana* produces such fructifications freely; they have been found in abundance in the United States and other regions where this fungus flourishes. Of *S. cinerea*, Professor Barss says: "In tests it failed to produce the apothecial (spore-cup) stage under conditions that gave abundant development of this stage with the ordinary Brown Rot fungus." The general inference is, then, as recent research has shown, that the common American Brown Rot fungus (referred to here as *S. americana*) is quite distinct from either *S. cinerea* or *S. fructigena*, the common Brown Rot fungi of Britain and the European continent.

Although *S. americana* sometimes infests apples, inducing fruit-rot, the damage it causes to this crop is comparatively small, and Brown Rot of apples is not considered of any great economic importance in those countries where *S. americana* is the only Brown Rot fungus present.

Distribution of the Brown Rot Fungi.

The general distribution of the Brown Rot fungi has been studied with reference to the regions mentioned below. The evidence is based chiefly on the results of an examination, by the writer, of specimens and cultures received from these regions over a period of ten years.

The Continent of Europe.—Cultures and specimens received from various European countries show that the Brown Rot fungi of the Continent are similar

* Supposed at the time to be *S. cinerea* but now known to be *S. americana*.

† This fungus, referred to as *S. oregonensis*, has since proved to be *S. cinerea*.

to those found in Britain. *S. fructigena* is the fruit-rotting fungus particularly prevalent on apples and pears, but it is also found on stone fruits. *S. cinerea* is common in plums, cherries and apricots, not only infecting the fruit but also the flowers. *S. cinerea* forma *mali* probably occurs on the Continent, since a disease of apple trees, similar to Blossom Wilt and Brown Rot Canker of apple trees in Britain has been recorded.*

The United States.—As already stated, the common Brown Rot fungus of North America is that known as *S. americana*, a species not found in Britain ; and numerous strains, received from the eastern States, all proved to be of this species. Other strains obtained from California, however, conformed with the *S. cinerea* of Europe, and American workers have found this fungus not only in California but also in the neighbouring State of Oregon.

Canada.—Plums and peaches received from Ontario, and plums from the Fraser Valley, British Columbia, were found to be infected with the Brown Rot fungus, *S. americana*, prevailing in the United States, but cultures isolated from cherries grown in the south of Vancouver Island proved to be *S. cinerea*. The distribution of these two fungi in Canada, therefore, corresponds to that in the United States, *S. americana* being by far the more common form, whilst *S. cinerea* occurs on the Pacific seaboard.

In North America, therefore, *S. cinerea* appears at present to be confined to the Pacific Coastal regions. There is no evidence that *S. fructigena* occurs at all in North America.

Australia.—Mummified fruits of peach, nectarine and plum, received from New South Wales, all bore *S. americana*. Cultures, isolated from peach twigs in Victoria, were the same fungus, which appears therefore to be the prevailing Brown Rot organism of that Continent. *S. fructigena* has not yet been found there. The earlier descriptions of a Brown Rot fungus in Australia, said to be *S. fructigena*, were certainly not of this species, because the Australian fungus produced " ash-coloured spores."

New Zealand.—Here again the common American Brown Rot fungus prevails. Specimens received included apricot, peach and plum mummies, and peach twigs ; these all yielded *S. americana* in culture. As in Australia, *S. fructigena* has not been found. Cunningham, who has studied the Brown Rot diseases on the spot, writes : " In New Zealand, *Sclerotinia fructigena* does not occur."†

Other Countries.—With regard to other regions, where those fruits which are subject to Brown Rot infection are cultivated, cultures of *S. fructigena* have been

* It is doubtful whether *S. americana* occurs naturally in Europe. A culture of this species received from Holland was stated to have been isolated from a Bismarck apple ; if this fungus does occur naturally on the Continent, it is surprising that it has not been recorded more than once, as, where found at all in other parts of the world, it is so very prevalent.

† Cunningham, G. H.—Fungous Diseases of Fruit Trees in New Zealand and their Remedial Treatment. Auckland, N.Z., 1925, p. 228.

received from Japan and Manchuria, and of *S. cinerea* from Manchuria. Brown Rot has been recorded for South Africa, but the climate is too dry for the Brown Rot fungi to flourish there, and little damage is done by them.

Before entering on a discussion of the significance of this distribution, it may be well to summarize the foregoing conclusions in tabular form, in order to show clearly the type of damage caused by the respective Brown Rot fungi, and to indicate the regions where each is found; the absence of one or other species from certain important fruit-growing countries is emphasized.

Summary of Distribution.

Brown Rot Fungi.	*Distribution.*
Sclerotinia fructigena, the chief fruit-rotting fungus of Europe, is particularly destructive to apples and pears, and also infects the stone fruits.	Europe. *It has not yet been found in N. America, Australia or New Zealand.*
S. cinerea f. *pruni* is chiefly destructive as a blossom-wilt fungus, but on stone-fruit it also causes fruit-rot and infects young shoots.	Europe and the Pacific coastal regions of North America. *There is no evidence that this fungus occurs in Australia or New Zealand.*
S. cinerea f. *mali* causes blossom-wilt and Brown Rot canker of apple trees.	Europe. The disease has not been recorded elsewhere.
S. americana is primarily a fruit-rotting fungus of the stone fruits, but flowers are also infected. It causes comparatively little damage to apples.	North America, Australia and New Zealand. *It has not been found in Britain*, and it is doubtful whether it occurs naturally in Europe.

Consideration of Distribution Features.

The salient features which emerge from a consideration of the table are these:

(1) North America, Australia, and New Zealand are regions from which apples are exported in large quantities. Brown Rot of apples is not of serious importance in these regions at present, and this is correlated with the absence of the fruit-rotting fungus *S. fructigena*, although another Brown Rot fungus, *S. americana*, is present. What result would follow the introduction of *S. fructigena* into those regions cannot be predicted, but it appears probable, from what we know of the ravages of this fungus in Europe, that it would have an adverse effect, not only on the growing crop but also on the apples during transit. Apples in Britain often become infected with *S. fructigena* at or about the time of being stored, and there is frequently considerable wastage on that account in the early stages of storage. Apples taken from orchards infested

with *S. fructigena* would, undoubtedly, suffer similar wastage during exportation, unless extreme care was taken to eliminate diseased fruit during grading and packing. Cold storage would check the rot, but it would again resume its progress as soon as the temperature of the fruit became more normal.

(2) The Blossom Wilts of fruit trees, caused by *S. cinerea*, are only too well known to growers in this country, especially during wet springs; and in the humid regions of the Pacific coast of North America, where this fungus has also been discovered, similar damage is reported. It is conceivable, therefore, that the introduction of this species into Australia and New Zealand would result in loss from Blossom Wilts.

Blossom Wilt of apple trees, at present known with certainty only in Europe, is destructive on certain varieties, but whether it would be of economic importance on the varieties cultivated in the Dominions and in America cannot be stated. Its introduction to those countries where the apple crop is so valuable, is, to say the least, undesirable.

(3) As regards the British Isles, the chief feature of interest, yielded by the investigation, is the absence of *S. americana*, a fungus which is a destructive fruit-rot organism in America, Australia and New Zealand. Whether its introduction to these islands would be of serious moment it is impossible to say, but we know to our cost the havoc wrought by certain other fungi which have been introduced from America, viz.: American Gooseberry Mildew and Vine Mildew.

There are very good reasons, therefore, for supposing that the world's fruit crop would suffer in the event of the Brown Rot fungi becoming more widely distributed than they are at present, and the question arises: Is there any serious risk of these fungi being introduced into countries other than those in which they are now found? The three species must be considered separately.

(a) *S. fructigena* is essentially a fruit-rot fungus, and it is obvious, therefore, that it may be carried on the fruit. Since the demand for apples in this country is greater than the supply, it is unlikely that the fungus would be carried on fruit to our colonies or to the United States, nor are other European countries likely to be a source of danger in this direction. It has been pointed out, however, that this fungus passes the winter on the mummified fruit and sometimes (on soft-wooded varieties of apples) on fruiting spurs and on cankers, and it is possible that in this way the fungus might be carried on nursery trees. This risk is only present when trees which have fruited are exported, so that it is quite safe, as regards *S. fructigena*, to export "maiden trees" or even older trees which have not borne fruit.

(b) *S. cinerea* passes the winter on mummified fruits and also on flowering spurs and cankers, so that, again, trees which have not flowered will not, as a rule, carry the fungus. On plum trees, however, and sometimes on cherry trees,

the young shoots also become infected (producing the Wither Tip condition), and this may occur on quite young trees which have not flowered ; in such cases the fungus passes the dormant season in these withered shoots.

With regard to the possibility of transmitting the Brown Rot fungi of this country to the overseas Dominions or to America, the risk, therefore, appears slight, particularly with trees that have not flowered. Wither Tip is readily diagnosed, and the elimination of trees infected with this disease should present no difficulty. Older trees, which have flowered and are destined for exportation, should be examined for Brown Rot infection, and diseased trees discarded.

(c) Our own position with respect to the common American Brown Rot fungus, *Sclerotinia americana*, must now be considered. The possible means of importing this fungus into Britain are on (1) nursery trees and (2) imported fruit. As with *S. cinerea*, trees that have not flowered may, generally, be considered to be free from Brown Rot. Trees that have flowered should be guaranteed to be free from this disease. Though *S. americana* sometimes infects apples, Brown Rot is not considered a serious disease of this crop in regions where this particular species of Brown Rot fungus is the only one present. The introduction of the organism on imported apples, therefore, though not impossible, is probably not a serious menace, especially as this fungus, like our own *S. fructigena*, shows a tendency to turn stored apples black without developing the Monilia fructifications.

On the other hand, the situation is quite different with regard to the stone fruits. Plums, cherries and, particularly, peaches are readily infected by *S. americana*, and not only whilst they are on the trees, for there is considerable wastage by Brown Rot during transit, showing that infection occurs during the journey or that slight infection spots, which may be overlooked when the fruit is packed, develop later into definite rot. The relevancy of this fact to the distribution of the Brown Rot fungi becomes apparent when we consider the present-day methods of dealing with perishable food-stuffs by rapid transit and cold storage, so that it is now possible to send soft fruit considerable distances. In July, 1927, the writer was able (through the courtesy of Dr. Cyril West and Mr. Tomkins of the Low Temperature Station at Cambridge) to examine a number of diseased peaches which had been taken from a consignment imported from Georgia, U.S.A. When the writer received the peaches (seven in number) all bore Monilia fructifications, and, by removing a little of the infected pulp from each peach and transferring it to a plate of culture medium, a typical culture of *Sclerotinia americana* grew out in every case, showing that each was infected with the American Brown Rot fungus. The inference is that these diseased peaches had been infected imperceptibly when packed (or that some, at any rate, were so infected and had contaminated others) and that the rot had continued to develop and produce spores *en route*.

FIG. 1.
Early infection of apple, showing numerous fungal pustules.

FIG. 2.
Apples from store (October, 1927). These are seen turning black and bearing few pustules.

APPLES INFECTED WITH *Sclerotinia fructigena*. THIS FUNGUS HAS NOT YET BEEN FOUND IN NORTH AMERICA, AUSTRALIA OR NEW ZEALAND.

FIG. 3.
Sclerotinia fructigena on a pear.

FIG. 4.
Sclerotinia fructigena on plums.

Diseased specimens found in a consignment of peaches, which arrived at Covent Garden from Ontario about the middle of October, were also found to be infected with *S. americana*. The importation of stone fruits in a fresh condition into this country, from those regions where *S. americana* abounds, is therefore fraught with the danger of introducing a new destructive fungus, and is to be deprecated, unless such consignments are guaranteed free from Brown Rot when packed.

Summary.

(1) The chief fruit-rotting fungus of Britain and the Continent of Europe (*Sclerotinia fructigena*) has not been found in Australia, New Zealand, and North America.

(2) The Blossom Wilt fungus of plums and cherries (*S. cinerea* forma *pruni*), also common in Europe, is found in the Pacific coastal regions of North America but not in Australia or New Zealand.

(3) The Blossom Wilt fungus of apples (*S. cinerea* forma *mali*) appears to be confined to Europe.

(4) The Brown Rot fungus prevailing in North America, Australia, and New Zealand (*S. americana*) is not at present found on fruit trees in this country, but it has been found recently on peaches imported from America.

(5) The possibility and consequences of introducing any one of these fungi into a region where it is not found at present are discussed.

Section V

Entomology

NOTES ON MITES AND INSECT PESTS FOR THE YEARS 1928-30.

By A. M. MASSEE.

1. The Flat Scarlet Mite (*Tenuipalpus glaber* Donn.).

The increase in numbers of the Fruit Tree Red Spider in recent years made it necessary for the specialist and fruit grower to examine fruit plantations in closer detail than hitherto, in order that this troublesome pest might be detected in the field. As a result, other species of mites have been found which had been previously overlooked. A small flat scarlet mite *Tenuipalpus glaber* Donn. comes under this category. This mite, as indicated by its name, is bright scarlet in colour, and the dorsal surface of the body is ornamented by a series of irregular grooves. It is a very flat mite, and the legs are shorter than those of the Fruit Tree Red Spider. In addition, it is much more sluggish in its movements. The Flat Scarlet Mite is a gregarious species, and the fact that it spends the winter in the adult stage, hibernating at the base of spurs and buds, and in other sheltered places, at once distinguishes it from the Fruit Tree Red Spider, which spends the winter in the egg state.

Enquiries regarding the Flat Scarlet Mite have been received from Reading, Cambridge, Maidstone, Wateringbury and East Malling. The mites were so numerous on some apple trees in an orchard at Maidstone during the winter of 1928 that the spurs and branches of some of the trees were bright red.

Observations have proved that the Flat Scarlet Mite is a beneficial species, since it feeds upon moss, lichen and other foreign growths on the tree. This mite is sometimes found in amongst the fine hairs on the under-surfaces of the leaves, during the spring and summer months, but there is no evidence to suggest that it feeds on the foliage.

Theobald recorded this mite in 1905 (Journ. S.E.A. College, 1905, No. 14, p. 73), and refers to the species as being a beneficial red spider on fruit. It is mentioned again in Theobald's " Insect Pests of Fruit," 1909, p. 398, but in this instance there is a mistake, the species referred to is *Oligonychus ulmi* C. L. Koch, and not *Tenuipalpus glaber* Donn., as suggested by Theobald. The mite is also briefly referred to in a leaflet published by the Board of Agriculture in 1910.

2. The Beetle Mite (*Euzetes lapidarius* Mic.).

Specimens of this mite have been received from Worcester, Canterbury and several localities around East Malling. It usually occurs in old and neglected

plantations, and is not found in orchards which are sprayed annually with a tar distillate winter wash. It is to be regretted that the tar distillates destroy this mite since it is distinctly beneficial. It feeds upon moss, lichen and other growths on the tree. The Beetle Mite has been recorded on apple, pear, plum, cherry and nut. It winters in cracks and crevices and under loose bark on the tree trunks.

Its colour varies from brick red to dark red, while some specimens are shiny black. It is commonly called Beetle Mite because of the beetle-like hardness of its body. It is sometimes regarded as being a pest of the cherry, and it has been observed feeding upon the ripe fruits. However, its attacks are generally confined to those fruits which have split open or have been damaged after a period of wet weather, or from some other cause, such as an insect puncture. This mite is also referred to in an earlier report published by the Station.*

3. The Red Velvet Mite (*Allotrombidium fuliginosum* Herm.).

Enquiries concerning this very beautiful mite have been received from many parts of Kent during the past three years.

The Red Velvet Mite abounds on all kinds of fruit trees and bushes during April, when it may be seen walking up and down the shoots in a stately manner.

Many growers consider that the Red Velvet Mite is the adult stage of the injurious Fruit Tree Red Spider, and rejoice in finding it with the unaided eye. The two species are not related in any way.

Fortunately, the Red Velvet Mite is entirely predaceous in its habits, and it does not cause any harm to fruit trees. It spends the winter in the adult state, resting amongst dried leaves and in dry soil. Eggs are laid in the spring.

This mite has been observed feeding upon colonies of Woolly Aphis during the summer months.

4. The Strawberry Tarsonemid (*Tarsonemus fragariæ* Zimm.).

The Strawberry Tarsonemid was first recorded in this country in 1924 from Truro in Cornwall. Since that date it has been found in many other localities in this country. The following authentic records obtained as the result of examining material sent in to East Malling may be of interest : East Malling, Maidstone, Sevenoaks, Leeds, Swanley and Chislehurst (Kent) ; Scaynes Hill, Chailey and Lewes (Sussex) ; Wisbech (Cambs) ; Kingston Bagpuize (Berks) ; Hele and Newton Abbott (Devon) ; and also from the Tamar Valley.

Royal Sovereign seems to be more susceptible to mite attack than most other varieties, while Madame Lefebre is a highly resistant variety. The mite has also been found on Laxton on several occasions.

* Rept. East Malling Res. Sta. for 1924 (1925), pp. 165-166.

The Strawberry Tarsonemid has been recorded from several countries in Continental Europe and is regarded as being a serious pest of the cultivated strawberry in Germany and Denmark.

A closely allied mite, *Tarsonemus pallidus* Bks., occurs in the United States of America and in Canada, and is described as being a pest of the strawberry in those countries.

Investigations upon the control of this mite are being carried out in the field and laboratory.*

5. The Gooseberry Bryobia (*Bryobia nobilis* Th.).

Some interesting observations upon the Gooseberry Bryobia (Red Spider) were noted during the spring of 1930. On April 9th thousands of gooseberry mites were observed migrating from numerous cracks and crevices of an old gate post, situated at the entrance to a field in which gooseberry bushes were growing. The mites were making their way across the headland of the field, and were observed to feed on various weeds growing there. Dandelions and docks were particularly numerous, and the mites appeared to prefer these plants, for they fed upon the leaves for several days. Eventually all the mites disappeared from the weeds on the headland, and they were found feeding upon the leaves of the gooseberry bushes. Most of the mites were found on the under-surfaces of the leaves on the young growths near the ground, and towards the centre of the bushes. Previously the Gooseberry Bryobia had not been detected on the gooseberry bushes. Later in the season all the gooseberry bushes were badly infested with mites and spraying operations were necessary in order to control them.

Another interesting observation was made in March, 1929. Thousands of acari, which later proved to be the Gooseberry Bryobia, were observed migrating from two of the buildings at the Research Station. Closer observations showed that the mites had been hibernating in sheltered positions on the inner side of the steel window frames and in some small cracks below the window ledges. When the mites had left the buildings they were noticed feeding on docks and other weeds growing on a waste piece of land near by.

Gooseberry bushes were not growing near the buildings and it is not known where the mites came from in the previous autumn. Some of the mites were collected and transferred to a gooseberry bush growing in a pot. The mites fed quite readily, and after a few days the plant was defoliated.

Mr. James Ritchie also recorded this mite as invading a dwelling house.†

* *Gard. Chron.*, 1930, **87.** 3rd Ser. No. 2,250, pp. 110-111.

† *James Ritchie*, "Clover Mites (*Bryobia praetiosa*) Invading a Dwelling House." Scottish Naturalist, 1929. p. 126.

6. The Nut Gall Mite (*Eriophyes avellanae* Nal.).

It is generally considered that the Nut Gall Mite is not a serious pest, since it confines its activities to the leaf buds and does not injure fruit buds of the nut. However, from records obtained in the Maidstone district it is quite evident that the Nut Gall Mite attacks the female flowers and the catkins in addition to the leaf buds.

This mite has been increasing in many plantations during the last three years, and nut growers are advised to examine their nut plots during February to ascertain whether this mite is infesting the flower buds and catkins. When the female flowers are attacked they become swollen in the same manner as the leaf buds.*

7. The Hop and Currant Red Spider (*Tetranychus telarius* L.).

It has been known for some years that the red spider (*T. telarius* L.) which occurs on the hop and currant leaves in the summer months, hibernates during the winter in the adult state, but there appears to be some doubt about the location of the winter quarters selected by the mite for hibernation purposes.

Observations upon this aspect have been obtained during the winters of 1928 and 1929, and it has been established that most of the mites spend the winter in the soil. It has been noted that the mites turn brick red in colour during September, and cease to feed at this period until the following spring. Many of the mites migrate from the leaves to the soil, where they may be found sheltering under stones and clods of earth.

Soil taken from hop gardens and currant plantations which had been heavily infested with red spider during the summer months, was examined each month from September to March for two seasons, and little colonies of hibernating mites were found on each occasion after careful searching.

It is agreed that some mites may hibernate in the cracks in the hop poles, others in old dead leaves, etc., but it is considered that the majority hibernate in the soil.

8. The Strawberry Red Spider (*Tetranychus telarius* L.).

During 1929 the Strawberry Red Spider was common everywhere in Kent, and growers from many districts enquired about this pest.

It has been known for some time that the Strawberry Red Spider is the same species as that found on the hop, the black currant, and numerous plants grown under glass, but it had not been established that the life-cycle and habits of this mite were the same on one host plant as on another. Therefore some observations upon the life-cycle of this acarus were obtained from a mite-infested plantation of strawberries situated at East Malling.

* Bull. Ento. Res., 1930, **21.** pp. 165-168.

In the first place it was discovered that the red spiders finished feeding upon the foliage during September, that they became brick red in colour, and then sought out sheltered places in which to hibernate for the winter. Most of the mites buried themselves in the crowns of the plants, while a few attached themselves to dead and dried-up leaves. Others were found in the soil under stones and clods of earth near the roots of the plants. Little colonies were found inside hollow pieces of straw which were scattered about the field. The red spiders remained in these sheltered quarters until the spring. By the middle of March most of them had left their winter quarters and were observed feeding on the younger growths of the plants. Some continued to hibernate until April.

On April 9th the red spiders were very active and their eggs were found on the leaves. Immature forms were not detected until some time later. From the beginning of May until September, adult mites, immature forms and eggs were all found on the leaves at the same time. This indicates that mites of more than one generation were breeding on the plants at the same time. It was also noted that the actual mite population varied considerably according to weather conditions. Thus, during the warm, dry weather of 1929 the red spiders bred very rapidly, and under these circumstances the growth of the plants was slightly checked. In wet, cold weather the mites breed very slowly and the plants grow away freely.

In the spring of 1930 this red spider was very common in many strawberry plantations, and a bad attack, similar to that of 1929, was expected in many quarters. However, as soon as the rainy period set in during July the red spiders were checked, and were not troublesome for the remainder of the season.*

9. Mushroom Mites.

Very little has been published in this country upon Mushroom Mites, and our knowledge of these interesting animals is very incomplete.

Specimens of these mites have been received from Kent and Sussex, and they are reported to be causing a good deal of damage to mushroom beds, especially in West Sussex.

Three species of mites are chiefly concerned, viz. *Caloglyphus kramerii* Berl., *Oppia nitens* C. L. Koch, and *Linopodes motatorius* L. The first two species are definitely injurious, while the latter is a predaceous mite which feeds upon one of the former species.

O. nitens Koch is well known on the Continent and is recorded as infesting cultivated mushrooms which are grown extensively near Vienna. *C. kramerii* Berl. is also very injurious and may cause considerable trouble to mushroom growers.

* *Gard. Chron.*, 1930. **87.** No. 226, April 26th, p. 335.

L. motatorius L. is entirely predaceous and it feeds upon the injurious species *C. kramerii* Berl. This mite was first recorded as long ago as 1718 by Joblot, and has been referred to in many publications since that date. This mite can be distinguished at once from the two other species by its very long legs, and by the fact that it runs about the mushroom beds very rapidly. The injurious species are sluggish in their movements.

The writer is greatly indebted to Dr. A. C. Oudemans for the determination of the three mites referred to above.

10. The Clay Coloured Weevil (*Otiorrhynchus singularis* L.).

The Clay Coloured Weevil is a well known pest of soft fruits and newly grafted apple trees, but on account of its obscure habits it is often overlooked.

In latter years this insect has appeared to be increasing in numbers; it has been reported from many parts of Kent, and it has been found attacking one year old black currants and the scions of grafted apple trees.

This weevil is very difficult to find because it buries itself in the soil during the daytime and does not come out to feed until nightfall.

Some young black currant bushes growing at the Research Station were attacked by this weevil in the spring of 1929. The weevils fed upon the foliage, the petioles, and even upon the tender shoots of the black currants. Some of the bushes were defoliated, while some of the shoots of many other bushes were stripped of their leaves. The terminal buds of a number of shoots were eaten out by the weevils, causing the branches to fork or grow out in a stunted manner. See Fig. 1.

The infestation was finally checked by the combination of cultural measures and spraying with an arsenical wash.

The plantation was cultivated by means of a horse-drawn cultivator, and the soil under the bushes was hand-hoed to disturb the weevils by destroying their hiding places. On the following morning the bushes were sprayed with an arsenical spray, applied at the rate of six pounds of lead arsenate paste to 100 gallons of water. The control obtained was regarded as complete.

This weevil also attacks newly grafted apple trees, and this kind of injury has been reported from many districts in the Maidstone area and also from Eynesford, Kent.

The weevil destroys the buds of the scions as soon as they commence to grow, and eventually the graft dies or at most produces a weak growth. Some hundreds of grafts were destroyed in this manner in the spring of 1930. The grower had not seen the weevil at work, and assumed that the damage had been caused by birds.

Fortunately this type of injury can be prevented quite readily by painting the grafts with lead arsenate, which should be made up in the form of a paste,

and applied by means of a brush. The greasebanding of the trees also prevents attack, since the Clay Coloured Weevil cannot fly from one tree to another. This and similar weevils do not possess wings.

11. The Black Weevil (*Magdalis cerasi* L.).

This weevil has not been reported as a pest of hard fruits, but since it has been noted feeding upon apple foliage on several occasions during 1930, it seems worth while recording it upon that host plant.

It is known to occur in some fruit plantations at East Malling and, in addition, numerous specimens of this weevil have been sent here from a fruit farm in West Sussex.

12. The Little Longicorn (*Tetrops praeusta* L.).

This pretty little Longicorn beetle has been found in a number of localities in Kent and Sussex.

It occurs on the foliage of the apple and pear, especially during May and June, but up to the present it has not been observed to cause any material damage to the trees or fruits. In nearly every case it has been found in old and neglected orchards, and it is probable that the larva of this beetle tunnels into the dead shoots, where it feeds in a manner similar to that of the larva of the Apple Clearwing Moth.

13. The Hop Flea Beetle (*Psylliodes attenuata* Koch).

This Flea Beetle caused a good deal of trouble in many hop gardens during May and June, 1930, and requests for information about this pest were received from Cuxton, Marden and Maidstone.

The hop gardens of the Research Station were also infested by this Flea Beetle, and the growth of many of the hills was checked for some weeks. Some of the young growths were so badly affected that they had to be removed. The leaves were attacked and many were skeletonized in bad cases. See Fig. 2.

The infestation was first noted during the first week of May, and the damage was very severe by the third week of the month.

Control measures were undertaken, and it was found that dry spraying with a three per cent. nicotine dust, and wet spraying with lead arsenate and also with nicotine, did not materially reduce the attack.

Finally, a somewhat primitive method of control, that of jarring the beetles off the bines on to boards covered with greasebanding material, was tried. The jarring process had to be repeated at each hill before the beetles were reduced sufficiently to allow the hops to grow away from them. Nevertheless the control was complete.

14. The Strawberry Anthonomus (*Anthonomus rubi* Herbst.).

Fortunately the Strawberry Anthonomus does not appear to be very common in Kent, but where it does occur it is reported to be a great source of worry to the strawberry grower.

It has been common at Plaxtol, near Sevenoaks, for many years, and recently it has appeared at Ide Hill, near Sevenoaks. Locally the weevil is known as the "Elephant." Enquiries from Sussex show that this pest is very common in the strawberry growing districts near Lewes.

At present no control measures are known, but growers are advised not to plant strawberries where this insect is known to occur.*

15. The Pear Midge (*Contarinia pyrivora* Riley).

Severe outbreaks of Pear Midge have occurred in different parts of Kent during the last three years, and enquiries regarding the control of this pest have been received from Southfleet and Faversham.

Several pear plantations at Southfleet have been attacked by Midge each year since 1918, and during 1927 the infestation was so severe that most of the fruits were spoiled.

Some of the recognized measures of control were carried out on the farms at Southfleet, and it was found that the picking of the fruits by hand, and treating the soil with insecticides proved to be of very little value.

In 1928 and 1929 cultural methods of control were resorted to, and very satisfactory results were obtained.

One orchard at Stonewood, Southfleet, consisting of two acres of Dr. Jules Guyot and Fertility Pears, was cultivated one day each week for six consecutive weeks by means of a horse-drawn Planet Junior cultivator. The cultivator was set with wide shoes so that all the ground was moved. The cultivating operation was started in this orchard on June 10th, 1929 (at this date most of the midge larvæ had left the trees, and were to be found in the soil), and continued until July 5th, inclusive. In order to make certain that all the soil was moved, the orchard was cultivated along the rows between the trees, across the rows, and also diagonally. In addition, the soil around the trunks of the trees was hoed by hand once each week for six consecutive weeks. The soil under treatment was of the nature of a gravelly sand.

A pear plantation adjoining, consisting of Dr. Jules Guyot, Fertility and Williams, was left untreated as a "control." Both orchards were badly attacked by midge in 1929.

Both orchards were examined again two weeks after the blossoms had fallen in 1930. Counts made on the untreated "control" trees indicated that 80 per cent. of the fruits were attacked by midge. Very few midge infested

* *Fenoulhet, G.*, Journ. S.E.A. College, 1907, No. 16, p. 105.

fruits were found on the treated trees, and these were always found on the outside rows adjoining the control trees. This tends to show that the midge does not travel very far in one season.

There is no reason to doubt that the cultivation alone destroyed the larvæ, and that Pear Midge can be controlled by cultural means, provided that the weather conditions are suitable, and that the cultivation is carried out for a sufficient length of time at the correct season.

Another orchard at Southfleet was treated in a similar manner, and Pear Midge was completely controlled in that orchard also.

The cultivating operation was carried out under the strict supervision of the writer.

16. The Leaf Edge Curling Black Currant Midge (*Dasyneura* sp.).

This midge cannot be considered a common insect in this country, since it has been recorded from very few localities. However, about three years ago it was recorded from Matfield, Kent, where it was causing considerable damage to black currants.

The damage caused to black currant leaves by this midge is similar in many respects to that caused to pear leaves by the Leaf Edge Curling Pear Midge.

The midge was first noted at Matfield on June 27th, 1928. The minute orange larvæ of this midge were found in the folds of the edges of the leaves, which were badly twisted and curled inwards. Many of the leaves were badly distorted, and a dozen or more larvæ were present on each leaf so affected. The infestation increased, and by July 16th most of the young leaves of some hundreds of bushes were damaged by the midge larvæ. The bushes were examined again on August 1st, but by this date all the larvæ had left the leaves.

After a careful search one or two larvæ were found in the soil. Thus it is possible that the midge spends the winter in the soil in the larval state. However, this observation will have to be confirmed.

The larvæ cause the tips of the shoots to branch and, in bad cases of attack, the shoots become nettle-headed. The new growths which appeared later in the season tended to obscure the damage caused by the larva a month or so earlier in the year, but on close inspection the damage was still apparent.

The midge appeared again on the same bushes during the summers of 1929 and 1930. The bushes were sprayed with a strong nicotine wash as soon as the damage was noticed, but very little success was obtained by this treatment.

17. The Feathered Thorn (*Colotois pennaria* L.).

The Feathered Thorn is generally distributed throughout the British Isles, and although the caterpillar of this moth has been recorded upon the apple, such trees as the Oak, Hawthorn, Birch and Poplar appear to be the more usual hosts.

However, this insect is quite common on apples in the East Malling district. In 1929 and 1930 batches of eggs of this insect were found on the apple twigs during January. A hundred or more eggs are laid in one batch. They are olive green in colour. The caterpillars which hatch are typical Geometrid larvæ, and they feed upon the foliage. At present it is not a serious pest.

18. The March Moth (*Anisopteryx aescularia* L.).

The March Moth has been abundant in the Swanley district for a number of years, but curiously enough it has not occurred in other parts of Kent, to any extent, until recent years.

During 1930 this moth was found everywhere in Kent, especially in apple orchards, and in certain centres it caused nearly as much defoliation of apples as the Winter Moth.

This pest cannot be controlled by winter washes, since the eggbands are not laid until all the winter washing has been completed.

Since the female March Moth is a wingless species it is readily caught on greasebands, and this method of control, combined with spraying with lead arsenate in the spring, should be resorted to where this pest occurs.

19. The Pith Moth (*Blastodacna atra* Haworth).

This very troublesome pest is increasing in parts of Kent, notably in the East Malling district, and in one orchard most of the shoots of some young apple trees were attacked by this insect. The variety Lord Derby seems to be very susceptible to attack, and the majority of the spurs of this variety die after the larva of this moth has tunnelled in them. The larva frequently attacks the terminal bud, thus causing the branches to fork and tending to make the tree grow in an uneven manner. It is also very probable that the canker fungus follows Pith Moth infestation ; at any rate the two troubles are found on the same trees in very many instances.

20. The Codlin Moth (*Cydia pomonella* L.).

Small outbreaks of the Codlin Moth occur each year in different parts of Kent, but the degree of attack varies greatly, especially in large plantations, from one season to another.

Until recently it was thought that the Codlin Moth outbreaks were mainly confined to small neglected orchards and gardens. In 1929 and 1930, however, this pest has been reported from many districts, and it is now not uncommon in commercial plantations in the Canterbury area and districts around Mereworth and West Peckham. More recently it has been found at Paddock Wood. Larvæ of the second brood were sent here from Canterbury this autumn.

It seems quite possible that another serious outbreak of Codlin Moth may be expected in a few years' time. Therefore growers are advised to look out for

this pest in their orchards, and endeavour to eradicate it before it gets out of hand, as it did several years ago.

The occurrence of this pest and many others, e.g. the March Moth, suggests very strongly that more arsenical sprays should be used in the spring, as they were prior to 1922. In 1922 the tar-distillate winter washes were first used commercially, and since that time the spring washes have been used less each year.

21. The Case Bearer (*Coleophora nigricella* Stach.).

The Case Bearer, in common with many other insects, is becoming more abundant in many Kentish orchards.

A very bad attack of Case Bearer occurred in an apple plantation at Marden during 1930. All the trees in the orchard were attacked by the larvæ of this moth and the infestation was so severe that on some trees five or six larvæ were found feeding on every leaf.

The Case Bearer has also persisted in an apple plantation at East Malling for the past five years, and in spite of the repeated attempts to eradicate this pest, it is increasing year by year.

It is frequently said that a ten per cent. tar-distillate wash will destroy this insect, but in practice the Case Bearer is not affected by these winter washes. It is also very curious that a lead arsenate spray does not destroy this Case Bearer, since the larvæ feed upon the foliage. Where orchards have been thoroughly sprayed with an arsenical wash this pest still persists.

22. The Death's Head Hawk Moth (*Acherontia atropos* L.).

It is not pretended that this moth is a pest of agricultural crops, but since it always creates a certain amount of interest, it seems worth while putting on record the occurrence of this insect in this district during the last ten years.

A larva of this moth was found feeding upon potato haulm on September 22nd, 1922, at the Research Station. It was not reported again until 1927, when in June of that year a damaged specimen of the moth was sent here from Snodland. Another larva of the dark form was found on potato, at Ditton, near East Malling, during August, 1929. Two larvæ were found during September, 1930, one at Swanley and the other on a potato patch in a private garden at Birling, Kent.

23. The Rhododendron Bug (*Stephanitis rhododendri* Hor.).

The Rhododendron Bug was found at Matfield two years ago and it has been reported from Hawkhurst more recently. The presence of this insect can be detected by the leaves becoming brown and mottled on the upper surface.

At present this insect does not appear to be widely distributed in Kent. The rhododendrons growing at Matfield were imported from abroad, and there is reason to suppose that the Bug was introduced with the plants.* It is scheduled under the Diseased Plants Order of 1921 and 1922.

24. The Woolly Aphis Parasite (*Aphelinus mali* Hald.).

An endeavour to establish the Woolly Aphis parasite in Kent was first made during August, 1925, at East Malling, when a number of adult parasites were liberated in an apple orchard badly infested with Woolly Aphis. The parasites were placed amongst some well established colonies of Woolly Aphis.

They were not detected again after the date of liberation, and after a careful search parasitized Woolly Aphids were not noted anywhere in the orchard. Thus the first attempt to establish the parasites failed completely.

More parasites were introduced into the same orchard during February, 1927. Subsequent examinations showed that very little Woolly Aphis was present on any of the trees that season, and the parasite was not found anywhere in the orchard.

In March, 1928, a third attempt to establish the parasite was made at Chislehurst, Kent. The orchards at Chislehurst† were particularly suitable, since the trees were very badly attacked by Woolly Aphis, and many colonies were present during the early part of the year. This phenomenon is considered to be exceptional in Kent.

Many twigs bearing parasitized Woolly Aphids, and contained in gauze fly traps (to prevent predaceous insects destroying the parasites, and at the same time to allow the parasites to escape on emerging) were tied to selected trees in various parts of the orchards. Twelve such cages were used. Observations made later in the season showed that the parasites did not breed, and no trace of them could be found in any of the plantations.

During February, 1929, a further attempt to establish the parasite was made at Chislehurst. This time an orchard consisting of three acres of James Grieve, Beauty of Bath and Cox's Orange Pippin was selected. The planting was fifteen feet square.

Twelve cages, containing parasitized Woolly Aphids attached to twigs, were tied on selected trees in the south-west portion of the orchard. In March many colonies of Woolly Aphis were found on the trees, and by August many of the shoots were literally covered by this insect.

The parasite emerged some time before June, but the actual date of emergence was not recorded.

* *Fox-Wilson, G.*, "Insect Pests of Rhododendrons," Journ. R.H.S., 1925, **50**. 46-54.

† The writer is indebted to Mr. H. Marsham Townsend for allowing his orchards to be used for the purpose of these investigations.

[Photo W. Steer.

FIG. 1.

Goliath black currant shoots damaged by Clay Coloured Weevil. Right shoot, terminal bud and two leaf stalks destroyed. Left shoot, six leaf stalks bitten off by weevils.

[Photo W. Steer

FIG. 2.

Tutsham Hop Leaf skeletonized by Hop Flea Beetle.

They continued to breed throughout the summer and adults were actually observed up to the latter part of October, 1929. Parasitized Woolly Aphids could be found on all trees near to those on which the cages had been placed earlier in the year, and by November numerous parasitized Aphids were found forty-six yards away from the cages.

By November, 1930, the parasite had spread all over the three acres, and parasitized Aphids were found in all parts of the orchard. Neither living parasites nor living Woolly Aphids were found on this piece of fruit. However, in an adjoining plantation both Woolly Aphids and parasites were found during the summer of 1930, but the number of parasitized Woolly Aphids in this orchard was comparatively small.

The trees on which the parasite had established itself during the summer of 1929 were not sprayed during the winter of 1929-30, and the fact that many Woolly Aphids were parasitized during the growing season of 1930 indicates that the parasite lived through the previous winter.

Chislehurst appears to be the only place in which this parasite has been established successfully in Kent, and although many failures came before success, the trouble involved in this work has been well repaid.

This investigation was carried out in collaboration with the Ministry of Agriculture's Plant Pathological Laboratory, Harpenden. All the Woolly Aphis Parasite material being obtained from that source.

Summary.

Notes are given on twenty-four insect pests, mites and beneficial insects observed in Kent during the years 1928-30. Among the more important were the Strawberry Tarsonemus which has been reported from various centres in Kent, the Clay Coloured Weevil which commonly attacked the new growths of black currants and destroyed the scions of newly-grafted apple trees, the Hop Flea Beetle which attacked the leaves thus stunting the growths of the hop bines growing at East Malling, the Pear Midge which proved to be responsible for the destruction of a large percentage of the pear crop in orchards at Southfleet, the Leaf Curling Black Currant Midge, a new pest reported from Matfield, and the Woolly Aphis Parasite which was successfully established at Chislehurst after repeated failures in previous years.

THE RESISTANCE OF CERTAIN APPLE STOCKS TO ATTACKS OF THE WOOLLY APHIS.

By A. M. MASSEE.

INVESTIGATIONS in relation to the resistance of certain apple stocks to attacks of the Woolly Aphis (*Eriosoma lanigerum* Hausm.), have been in progress at East Malling since 1920, and in 1927 Le Pelley published a report* detailing the results obtained up to that time.

As a result of those investigations Le Pelley found that a number of apple seedlings proved to be immune from Woolly Aphis attack. These seedlings (Northern Spy x Doucin)† were deemed to be immune after unsuccessful attempts had been made to inoculate them with Woolly Aphis over a period of three years. However, it was not known whether all these seedling stocks would retain the immunity character if these rigorous tests were continued for a further period.

This doubt existed because one rootstock, No. XIII, which had been highly resistant to Woolly Aphis for two seasons proved to be susceptible when inoculated the third season. In addition, it is a well established fact that even susceptible rootstocks are very difficult to inoculate with Woolly Aphis in some seasons. This phenomenon has not yet been explained.

For these reasons it was decided to continue the investigations for an extended period, under glasshouse conditions.

The following immune seedlings (Northern Spy x Doucin), Nos. 779; 788; 789 and 793 were tested for a further period of four years in an insect-proof greenhouse. The seedlings were grown in pots which were plunged in ashes in the insectary. A number of susceptible varieties of apples were also grown in pots in the same house, thus ensuring an unlimited supply of Woolly Aphis for inoculation purposes.

During the seasons 1927 and 1928 no serious attempt was made to keep the seedlings free from attacks of other insects and mites, i.e., The Permanent Apple Aphis and the Fruit Tree Red Spider, and, as a result, the seedlings were somewhat weakened and unhealthy.

Direct inoculations were made from time to time, commencing in the first week of May and extending until October. The susceptible varieties of apples, severely infested with colonies of Woolly Aphides, were placed adjacent to, and

* Le Pelley, R. H. "Studies on the Resistance of Apple to the Woolly Aphis." *Journ. Pomology*. 1927, **6**. 209-241.

† Raised by Mr. M. B. Crane, of the John Innes Horticultural Institution, Merton.

even tied to, the seedlings that were being tested. This treatment ensured the migration of many thousands of immature Woolly Aphides from the susceptible to the immune seedlings, before they finally settled down to feed and start a fresh colony. The immature Woolly Aphides always walk up and down the shoots for some considerable time before selecting a place for feeding purposes. Cuts and wounds were also made on the shoots and stems of the various seedlings in the hope that this treatment would encourage the Woolly Aphides to feed upon them.

The above methods were used in an attempt to inoculate the seedlings during the years 1927 and 1928. It was not found possible to establish the aphides on any of the seedlings during this period; thus the immunity exhibited in earlier years was maintained. This fact is indeed encouraging because the seedlings were growing in an unhealthy state and the tests they received were very severe.

By this time layered stocks of each of these seedlings had been raised in the propagation beds by the Pomological Section, and the habits and merits of the seedlings were being noted. Six layers of each of the immune seedlings were available in the spring of 1929, and these were tested in a manner similar to that adopted for those of the 1927-28 series, under glasshouse conditions.

In this experiment the seedlings were encouraged to grow in a healthy manner and an attempt was made to keep them free from other insects and mites. It was found possible to achieve this object by spraying the layered stocks with a tar-distillate wash (5 per cent.) in the dormant season, and by spraying with lime-sulphur twice in the spring before the inoculations were commenced. Mildew was rampant on some of the plants in spite of this treatment, but this disease was kept in check by the hard cutting of affected shoots as soon as the mildew appeared.

In addition to the methods already described for attempting to induce infections, two new methods were also employed. A number of susceptible seedlings, heavily infested with Woolly Aphis and growing in three-inch pots, were found to be a very convenient means of transferring colonies of Woolly Aphis from one part of the house to another. Such seedlings could be placed on a branch or against the stem of the plant to be inoculated, thus giving the migrating immature aphides a reasonable chance of establishing themselves on the new host.

Finally, branches of Allington Pippin apple, which were very badly infested with Woolly Aphis were obtained from a neighbouring farm, brought into the insectary and tied to the young growths of the seedlings. Now, as soon as the cut branches commenced to shrivel and dry out, the Woolly Aphides on them migrated in search of fresh food, and many thousands were noted wandering about on the immune seedlings.

This drastic treatment was extended over the season of 1929-30, but none of the seedlings was attacked by Woolly Aphis. In a few instances one or two aphides appeared to be commencing to feed on the new growth of Seedling 779, but after a few days the aphides were dead. It should be noted in this connection that small colonies of Woolly Aphides have been observed feeding on Northern Spy, but only for a few weeks at the most.

The attempts to inoculate these seedlings have been made during a period extending over seven years ; all these attempts have failed to induce infection, so it is considered safe to assume that each of them, in common with Northern Spy is immune from attack.

Of these seedlings, Mr. Witt, Propagator at East Malling, states that Nos. 779, 793, and 789 are very promising, and material is now being raised to test their capability as stocks for use in commercial plantations. Unfortunately No. 788 proves to be too weak ; it is difficult to propagate, and is not considered to be of any commercial value.

As soon as sufficient material is available, it is proposed to send some of these immune stocks abroad for further testing, in order that their behaviour may be studied under conditions very different from our own.

Another apple stock, known by the name of Ivory's Double Vigour, received through the courtesy of Messrs. Barbier and Co., and originally raised at Ivory's Nurseries, Pargiora, New Zealand, has also been tested for its resistance to Woolly Aphis attack for a period of three years.

Ivory's Double Vigour stocks received the same treatment as that already described, and so far have proved to be immune. This stock makes sturdy growth in the propagation beds, and would appear to be very promising.

An unnamed apple growing in an orchard at Saharanpur, India, was sent here for testing purposes by Mr. Head, Deputy Officer of the Gardens there. The apple tree in question was growing in an orchard in which all the other trees were very badly infested with Woolly Aphis, while this particular tree proved to be free from infection.

Both hardwood cuttings, and seedlings obtained from the pips of this tree (open pollinated) were tested here during the years 1928-1930, but it was found, under our conditions, that the Woolly Aphis established itself after the initial inoculations had been carried out.

A further batch of seedling apples, raised by Mr. H. M. Tydeman, was tested in the autumn of 1930. The seedlings were as follows : Nineteen seedlings of the cross No. IX x No. XV, nineteen of XV x IX, and thirteen seedlings of Northern Spy, open pollinated.

The initial inoculations were made on September 4th, five Woolly Aphides being placed on each plant. The inoculations were repeated one week later,

and by the 15th of the month colonies of Woolly Aphides were established on each of the fifty-one plants treated.

It is a very curious fact that the month of September and the first half of October should prove to be the best time of the year for making successful inoculations with Woolly Aphis on apple stocks. This point has been noted for the past eight years, and, when apple stocks have appeared to be resistant throughout the spring and summer months, it is often possible to establish colonies on these plants in September, such colonies living throughout the winter, and breeding in the following spring.

The importance of this fact is fully illustrated by the recent trial already referred to in this paper. Fifty-one seedling apples were tested last September; in less than one month all were found to be infected, and the experiment was complete. Now, had these same seedlings been tested in the spring, it is more than likely that some of them would not have become infested with Woolly Aphis until quite late in the season, extending the experiment over a period of six months instead of one month.

Summary.

A number of apple seedlings (Spy x Doucin) remained uninfected by Woolly Aphis in preliminary trials, have now been tested for a further period of four years, and the immunity character exhibited in the first instances has been maintained.

Another apple rootstock, Ivory's Double Vigour, originally raised in New Zealand, has been tested for three seasons, and so far this stock has been immune from Woolly Aphis attack.

A number of selected apple seedlings bred at East Malling have also been tested, but each of these seedlings proved to be susceptible in the first trial.

THE TARSONEMID MITE OF STRAWBERRY.*

By A. M. MASSEE.

A NOTE† appeared in *The Gardener's Chronicle* last January recording the presence of a Tarsonemid Mite (*Tarsonemus fragariæ* Zimm.) upon the cultivated strawberry in England. Although very little was known about the mite at that time, it was pointed out that the same mite occurred in Germany, Sweden, Denmark, Norway and Russia and in those countries it seemed to be of definite economic importance. Recently the same species has been found in Holland.

The Tarsonemid Mite appears to be established in widely separated strawberry growing districts in this country. At present it has been recorded from East Malling, Maidstone, Leeds, Chislehurst and Sevenoaks (Kent); Scaynes Hill, Chailey and Lewes (Sussex); Wisbech (Cambridge); Hele (Devon); and from Truro (Cornwall).‡

In most cases the mite has been found upon the variety Royal Sovereign, but it is not confined to this variety alone since it has been recorded on Paxton and Laxtonian.

A closely allied mite (*Tarsonemus pallidus* Banks)§ has been found on cultivated strawberries in the United States of America and in Canada. In these countries the mite is regarded as a field pest of the strawberry plant, and investigations are in hand to determine whether the mite is responsible for the failure of the plants in some instances.

A comparison of the European and the Canadian species of mite has been made possible through the courtesy of Mr. W. A. Ross, Entomologist, Vineland Experimental Station, Ontario, Canada. The material received from Mr. Ross proves to be quite distinct from the European species. However, it is not surprising to find two distinct species of the same genus attacking the same host plant.

T. fragariæ Zimm. and *T. pallidus* Bks. may be distinguished from a systematic point of view by the characteristics of the posterior pair of legs of the males.

The third joint of the fourth pair of legs of *T. fragariæ* Zimm. bears two strong, stout fingers; a fine, short hair; and a very long bristle which is

* This article is reprinted from the Journ. of Pom. and Hort. Sci., 1930, **8.** 305-8.

† The Occurrence of a Tarsonemid Mite upon the Cultivated Strawberry in England. A. M. Massee. *Gard. Chron.*, Vol. LXXXVII (3rd Ser.), No. 2,250. pp. 110-111.

‡ While this paper was in the press the mite was found on strawberry leaves received from thirty more localities, and it seems to be present in the majority of districts where Royal Sovereign is grown.

§ The Cyclamen Mite (*Tarsonemus pallidus*) as a Field Pest of the Strawberry Plant. Geo. M. Darrow. U.S.A. Dept. Agric., Nov., 1928 (a stencilled memorandum with 2 figs.).

acuminate at apex. The third joint of the fourth pair of *T. pallidus* Bks. possesses two short spines, which are very much weaker than those of *T. fragariæ* Zimm. A short, clavate hair is present and also a very long thread-like hair.

The second joint of hind leg of male *T. fragariæ* Zimm. bears a very strong, short bristle at base, while the corresponding joint of *T. pallidus* Bks. bears a long, tapering bristle at base, and also a fine hair towards apex. The characters referred to above are sufficient for separating the two species. The females of the two species are very much alike, and so far no character has been observed to separate the species correctly.

Observations in the field in this county have shown that the mite occurs in greater numbers upon unhealthy plants and in view of this important fact a preliminary experiment has been undertaken to determine the nature of damage, if any, caused by mite upon the strawberry plant.

For this purpose twenty-four healthy Royal Sovereign strawberry plants, growing in pots were selected and kept in an insect proof greenhouse. The plants were divided into two batches of twelve, one batch being infected with mites and the other being left untreated as a " control " to the former series.

Although all the plants were known to be free from attacks of Aphis, Red Spider and the Tarsonemid mite they were thoroughly well sprayed with lime-sulphur and a white oil emulsion spray as a final precaution. The control plants were kept at some distance from the infected ones, and were sprayed each week from the beginning of May to prevent any possibility of mite infection. The pots were grease-banded also to prevent any insects or mites from reaching the plants from the staging.

Three female tarsonemid mites were placed on a young unopened leaf of each of twelve plants to be infected. The first infection was made on May 7th. The infections were repeated on the 10th and 13th of May. In the latter infections approximately six mites were placed on the foliage of each plant.

A week later the plants were examined in detail and living mites were found on each plant. Eggs were present on the foliage of some of the plants, and on one plant immature mites were present.

By the end of June all the plants in the infected series were literally covered by adult and immature mites and their eggs. It seems quite evident, at least under greenhouse conditions, that the mites breed very rapidly and when it is remembered that only nine female mites were put on each plant, the rate of reproduction must be enormous. Up to the time of writing a male tarsonemid mite has not been found on any of the plants, which indicates that the female can breed without the presence of the male. The control plants have been examined at frequent intervals throughout the season and it may be said quite definitely that they have not been attacked at all by any species of aphis, red spider or mite.

The first sharp distinction between the infected and the control plants was noticeable by the first week in July. The control plants were producing many sturdy runners and the foliage was of a fresh green colour. On the other hand the infected plants were weakened very considerably and the foliage was of a dull silvery-green colour. The runners were very much distorted and weak. At the end of July all the control plants were still quite normal, and healthy runners were still growing quite freely.

By this time the infected plants were all in a very unhealthy condition, and the silvery appearance of the foliage gave one the impression that they were badly affected by mildew. Most of the young leaves were weak, deformed and brown in colour. The older leaves were all crinkled, of an olive green shade, with the edges a sickly yellowish green. In addition to the crinkling the edges of the leaves are turned upwards (spoon shaped) and the texture becomes very brittle. In very many cases the newly developing leaves turn a silvery-brown colour and remain dwarf. Sometimes these leaflets do not develop and those very badly affected dry up completely. (See Fig.)

Exactly the same description can be given of the runners. All the developed leaves on the infected runners show the typical crinkled appearance, the texture becomes very brittle and the plants are very dwarfed and stunted.

Unhealthy plants have been found in the field showing symptoms exactly similar to those described above, and in each case the Tarsonemid mite has been present. This fact may prove to be of considerable importance to the strawberry grower.

Nature of Attack.

One very important point that must be emphasized is the way in which the mite attacks the plants. All the damage caused to the leaves by the mites is done in the very early stages before the leaflets are unfolded. When the leaves are fully opened, very few, if any, mites are to be found upon them. As mentioned in the previous article, all tarsonemid mites dislike strong sunlight, and therefore seek shelter in the unfolded leaves, where they feed and breed. Exactly the same thing happens to the runners. The damage is completed before leaves are developed, and as a result the runners are somewhat weak and difficult to establish. There is a natural migration of mites from the parent plant to the runners as soon as they begin to grow.

It is quite possible that this mite has been present in this country for many years, but has been overlooked on account of its obscure habits.

Although the mites prefer sheltered places for breeding purposes, it is evident that they can travel very quickly, because they are always to be found on young runners as soon as they are produced.

[*Photo. W. Steer.*

A Mite-infested Royal Sovereign Strawberry Plant.

Twenty-four self infested runners have been raised from the infected plants for observation purposes. Of these, eight have died and the remainder are in a very unhealthy condition. There is little doubt that the plants were killed as a result of mite attack. It should be mentioned that the mite infestation was very severe under the greenhouse conditions and it is unlikely that the plants would have died had they been growing in the field.

Thirty-six runners were raised from the healthy "control" plants (many more could have been raised if desired) and it is proposed to use these for the continuation of the experiment next year. These runners will be especially valuable since they are selected plants and are definitely known to be free from any kind of insect or mite attack.

Although it is not possible to form any definite opinion from the result of one year's investigation, there is reason to believe that the Tarsonemid mite (*Tarsonemus fragariæ* Zimm.) may be one of the causes of the failure of strawberry plants in this country.

The writer is indebted to Mr. W. Steer for taking the photograph and to Mr. A. Tidy for the interest and untiring energy he has displayed in tending the plants from the cultural point of view.

Summary.

In a preliminary experiment healthy Royal Sovereign strawberry plants became diseased and malformed when attacked by the strawberry mite (*Tarsonemus fragariæ* Zimm.).

As a result of mite attack the leaves become crinkled and very brittle. Newly developing leaves turn a silvery-brown colour, and in some instances dry up.

Attacked runners are also malformed and as a result unhealthy plants are produced.

All the "control" (non-infected) plants remained perfectly healthy and produced healthy runners.

THE LOGANBERRY BEETLE.*

By W. STEER.

The raspberry and loganberry beetle, *Byturus tomentosus* F., is in most districts the worst pest with which growers of raspberries and loganberries are troubled. Many loganberry plantations have been grubbed out on account of the depredations of this pest, which produces small deformed and maggoty fruit which is of low market value and largely unfit for bottling or canning. Loganberries suffer more severely from its attacks than do raspberries. This is partly because the beetle shows some preference for the former fruit, but partly also because raspberries show fewer signs of infestation when marketed, as the grubs tend to remain in the plugs which are left on the plants.

This beetle is widespread on the Continent, being found in Germany, France, Russia and Holland, whilst in parts of America a closely allied species causes very similar damage.

Life History.

In the spring, adult beetles emerge from the soil in which they have hibernated, appearing first late in April and in ever-increasing numbers throughout May.

At this time they are pale brown, covered with yellowish pubescence, and are of a clean and bright appearance (var. *flavescens* Marsh.). Later on (in June) they become darker in colour and the pubescence becomes grey, sometimes tinged with green.

The beetles, which are about $\frac{1}{6}$-inch long, fly readily, especially in sunny weather, and make their way to various flowers in which to feed. They may often be found in the flowers of hawthorn and apple, sometimes doing a certain amount of damage to the latter. On one occasion the writer observed them damaging flowers of Morello cherries. They also feed on unopened flower buds of raspberries and loganberries, burrowing into the buds and destroying the contents, or nipping them off at the base. This damage is usually worse when there is no hawthorn blossom in the vicinity.

As soon as the flowers of raspberries and loganberries begin to open, the beetles frequent them and as many as five or six may often be found crowded into a single blossom. Although they feed to some extent on the petals and

* A study of this pest was begun at East Malling by the writer in 1927 and experimental work is still being carried out. The present paper constitutes a progress report incorporating results so far obtained. A more technical paper dealing in greater detail with the life history is in course of preparation.

sexual organs, the nectar in the cup of the flower appears to be the chief attraction.

After feeding for a while the beetles mate, prior to laying eggs. Eggs are laid over a long period, beginning on raspberries early in June, but the length of the oviposition period of the individual is not known. The female prefers to lay her eggs in blossoms which have shed their petals and set their fruit. Eggs may be found attached to the stamens and pistils or lying in the cup of the flower. The egg is creamy white, smooth and shining, rather more than a millimetre in length and about half a millimetre wide. It is an elongated oval tapering more gradually towards one end than to the other.

Hatching begins about the middle of June, and each egg normally hatches when the fruit on which it has been deposited is swelling rapidly, ten to twelve days after the egg has been laid. The minute larva crawls over the surface of the fruit, nibbling here and there, and then bores its way in, usually at the base, eventually reaching the receptacle or " plug " in which it tunnels, feeding on the surrounding drupels.

When fully fed the larva drops or crawls to the ground and makes its way into the soil, where it constructs a small earthen cell in which to spend the winter, the depth varying from half an inch to a foot or more below soil level. After about five weeks spent thus in the soil, the larva changes into the pupa, which at first is white with dark eye-spots, but later becomes yellowish-brown with prominent black eyes and blackish wing pads. After a further period of four or five weeks as a pupa, the pupal skin is shed, and the adult disclosed. The adult beetle is at first soft and very pale but gradually hardens and takes on the yellowish colour of those individuals to be seen in the spring. It does not move from its pupal cell until April or May, when it leaves the soil and seeks blossoms in which to feed.

For many years it was thought that it spent the winter as a pupa. Taschenberg (7), Whitehead (12), Ormerod (5), Theobald (8) and others state that the larva spins a cocoon under rough rind and in cracks on the canes and support stakes, and in the soil round the bases of the canes, and that it hibernates there as a pupa. Observations at East Malling in 1927 and 1928 showed that no cocoon is spun, that it does not spend the winter as a pupa and that hibernation seems to occur only in the soil. Subsequently Warburton's papers (11) came to the writer's notice and it was found that the East Malling work entirely corroborated the earlier work of Warburton.

Although it never seems to hibernate in the pupal stage, evidence has been obtained at East Malling that some larvæ, i.e. those which enter the soil very late, may pass the winter and following summer as such, pupating in August, becoming adult in September and spending their second winter in the soil as adults. The ultimate fate of these has not yet been determined.

Damage.

The damage done by the raspberry beetle is familiar to everyone and consists of :

(1) the destruction of the buds by the adults,

(2) the production of small and deformed berries by the feeding of adults and larvæ, and

(3) the infestation of the fruit by the larvæ.

Counts of ripe raspberries grown at East Malling Research Station in 1928 showed an infestation of over 37 per cent., and a loganberry plantation near the Station had fruit infested to the extent of over 55 per cent. in 1929. This plantation has since been grubbed.

The raspberry crop in 1930 was, in many districts, more heavily attacked than usual, possibly on account of ideal weather conditions for egg laying.

Control Measures.

Methods which have been tried for the control of this pest may be classified under three headings :—

(1) mechanical measures,

(2) the use of soil insecticides and fumigants, and

(3) spraying.

Mechanical Measures.

Large numbers of beetles may be trapped in the spring by shaking the canes vigorously over sticky boards or tarred sacks. This is best done on a dull day or early in the morning, as the beetles fly readily in sunny weather. However, in order to obtain any conspicuous measure of control, it is necessary to collect the beetles almost daily over a period of several weeks, and therefore *this method is obviously not applicable to large areas.* In a small garden the method becomes more practicable.

Shallow cultivation, where it is possible, would no doubt destroy many of the pupæ near the surface. It would have to be carried out during September when there are most pupæ. If either the larvæ or the adults are disturbed they are unharmed and crawl into the soil again.

Poultry allowed to run in a plantation during the months of August, September and October might have a beneficial effect, especially if cultivation could be carried out at the same time. It is quite likely that the beetle could be considerably reduced in numbers by the use of poultry in the spring (chiefly in May), since chickens will eat the beetles very readily.

If the fruit is infested to such an extent that it is unsaleable, the next year's infestation can be reduced by removing and destroying the whole of the fruit clusters when the fruit begins to ripen. By this means the larvæ are destroyed

before they can enter the soil. This method is more likely to be successful in isolated gardens and plantations, where there is less fear of fresh infestation in the spring by beetles flying in from neighbouring raspberries and loganberries.

Soil Insecticides and Fumigants.

Such substances as Naphthalene, a proprietory naphthalene preparation, Calcium Cyanide and a Tar-Distillate winter wash, did not give promising results when applied to the soil at East Malling. Soil and weather conditions in this country are not favourable to the use of soil insecticides generally, but apart from this fact there are two objections to their use against the raspberry beetle, viz. the difficulty of mixing the insecticide properly with the soil, and the lack of concentration of the larvæ and pupæ in the soil. The raspberry is a shallow rooting plant and this hinders both the application of a soil insecticide and the use of deep cultivation (which might in itself help by disturbing many of the pupæ). Again, although many larvæ doubtless enter the soil close to the canes, others wander over the surface for some distance before entering, and may bury themselves anywhere between the rows. This would necessitate the application of an insecticide uniformly to the whole of the soil area of a plantation. Moreover, although the majority descend no further than about two inches, many larvæ burrow as deeply as twelve inches or more, where there is little hope of reaching them.

Spraying.

As early as 1903 Theobald (8) used arsenate of lead as a means of checking the ravages of the adults on the buds. He admitted, however, that it was not to be relied on. The writer has also observed in raspberry plantations sprayed with arsenate of lead for this purpose that, although the beetles were at first reduced in numbers, there were quite as many to be found again after a day or two. The spray in such cases appears to act merely as a temporary repellent. If the beetles were to feed to any extent on the leaves, as the American species is reported to do, they would be killed more easily by this means.

Lees (1) in 1917 described attempts to control the pest by means of a Nicotine-Paraffin-Soap emulsion, but in a subsequent report (2) admits the method to be expensive and unsatisfactory. Lees and Peren also carried out trials (3, 4, 6) of lead arsenate sprays during blossoming time and concluded that three sprayings of arsenate of lead during this period would control the beetle. They hoped that it would be possible to obtain sufficient control by three years' treatment to be able to dispense with spraying for one or two seasons. Peren (6) stated that there is a slight financial loss if three sprayings are carried out, hence to follow such a spraying programme every year would be impracticable.

More recently Walton (10) has described experiments on the use of a petroleum-Agral extract of Pyrethrum. This spray considerably reduced the infestation on both raspberries and loganberries, and was considered to give a "commercial control" sufficient to warrant an extended commercial trial of similar Pyrethrum sprays.

East Malling Spraying Trials.

Research on the life history and control of the raspberry beetle has been in progress at East Malling for some time and preliminary spraying trials have been carried out with Lead Arsenate and other substances. Former work on the effect of Lead Arsenate spraying seems to have been based on the assumption that the adults are poisoned before they can lay their eggs. Observations on the habits of the pest, however, have led the writer to conclude that the real value of stomach poisons lies in their effect on the young larvæ which have to eat their way into the fruit. In the experiments described below, therefore, an attempt was made to apply the poisons to the developing fruits, before the eggs hatched.

Season 1928.

A small trial was carried out in a raspberry plantation where 37.5 per cent. of the fruits of unsprayed canes proved to be infested, on counts taken throughout the picking period. One spraying only was given, June 7th-8th, using a knapsack sprayer and driving the spray into the blossoms to leave a deposit on the swelling fruits. The rows were divided into lengths of which alternate ones were sprayed. Counts of the fruits were taken throughout the picking season, and the percentages of infested fruits from sprayed and control lengths compared.

The results (Table I) show that both lead arsenate at a strength of 4 lbs. paste to 100 gallons of water, and a proprietary Derris Root preparation at 2 lbs. to 40 gallons of water, reduced the infestation considerably.

Table I.

Raspberry Spraying Trial, 1928.

Treatment.	Total Fruits Counted.	Infested.	% Infested.	Difference.
Lead Arsenate	2,200	329	**15.0**	22.3
Control	2,200	821	37.3	—
Proprietary Derris ..	2,400	461	**19.2**	17.3
Control	2,400	877	36.5	—

Season 1929.

A badly infested plantation of loganberries was, through the kindness of Mr. Bennett of Ditton Court Farm, available for a spraying trial. In this plantation Lead Arsenate was used in a comparative test with a proprietary

Derris Root preparation, a white oil emulsion, and a home-made alcoholic extract of Pyrethrum. A technique similar to that of the 1928 experiment was employed except that a hand-power pump was used and two applications of spray given (on June 19th and 28th).

The strengths of the various sprays were as follows :—

Lead Arsenate : 5 lbs. paste, 2 lbs. Gelatine, 100 gallons water.
Derris preparation : 2 lbs. to 40 gallons water.
White Oil Emulsion : 1 per cent. (1 gallon to 99 gallons water).
Pyrethrum : Extract of 10 ozs. dried flowers per 12½ gallons wash (the flower heads were soaked for about 10 days in Methylated Spirit, filtered, and the filtrate mixed with 8 ozs. soft soap and water up to 10 pints, then diluted to 12½ gallons with water).

Four rows of loganberries each consisting of forty plants were used. Each row was divided into four plots of ten plants, sprayed and control plots alternating.

The white oil emulsion was tested for any possible contact effect on adults or eggs, but no measure of control whatever was obtained with it at the strength used. The other sprays were used with the object of poisoning the young larvæ as they bored their way into the fruits.

The results (Table II) may be summarized briefly. Lead Arsenate + Gelatine gave an almost complete control, the percentage of infested fruits being twelve from the sprayed and sixty from the unsprayed portions.

The Pyrethrum extract and Derris preparation did not materially reduce the infestation. The fruit from the Lead Arsenate plot was much finer and cleaner altogether than that from either the controls or the rows where the other washes had been applied.

None of the sprays had any appreciable effect on the adult beetles which were in the flowers at the time of spraying.

TABLE II.

Loganberry Spraying Trial, 1929.

Treatment.	Number of Fruits Counted.	Infested.	% Infested.	Difference.
Lead Arsenate	1,581	189	11.8	48.1
Control I	1,117	681	61.0 } 59.9	—
Control II	1,532	901	58.8 }	
Pyrethrum Extract (alcoholic)	3,007	1,535	51.0	1.5
Control	2,561	1,346	52.5	—
Proprietary Derris ..	2,137	701	32.8	13
Control	1,289	590	45.8	—

Season 1930.

A small scale trial was carried out on two rows of loganberries belonging to Mr. R. Smith of Trosley. The trial was primarily designed to test a proprietary Pyrethrum extract of the type described by Tutin (9) and used by Walton (10) against this pest. The plan of the experiment is set out below :

Plan of 1930 *Spraying Trial.*

P_3=three sprayings of Pyrethrum on June 5th, 11th, and 17th.
P_2=two sprayings of Pyrethrum on June 11th and 17th.
D_2=two sprayings of Proprietary Derris on June 11th and 17th.
C =unsprayed " controls."

The Pyrethrum wash at the strength used contained extract equivalent to approximately 1 per cent. of dried flowers. The Derris preparation was again used at the rate of 2 lbs. per 40 gallons of water.

The triple spraying (P_3) aimed at killing the adults, and the first of the three sprayings (June 5th) was applied before any eggs were observed. The double sprayings (P_2 and D_2) aimed at killing the young larvæ after hatching, before they could enter the fruits, and the first spraying (June 11th) was therefore applied after a considerable number of eggs had been laid but before any hatching was observed.

A knapsack sprayer was used with a fairly fine nozzle, and both washes were found to wet the flowers and fruits well, though the Derris was rather superior to the Pyrethrum in this respect. From a third to half a gallon of wash was used per plant at each application ; the plants were on the small side.

The weather at the time of the first spraying was warm but rather dull and windy ; the second and third sprayings were carried out in still, hot, sunny weather.

Six pickings of ripe fruit were taken and counts were made of the whole of the crop.

The results are set out in Tables III, IV and V.

The infestation was reduced on all the sprayed plots. Pyrethrum gave an appreciable amount of control as regards the first four pickings (Table III) but the reduction of infestation was not sufficient in the last two pickings (Table IV). The Derris sprayed plot (D_2) showed a remarkably low infestation throughout.

TABLE III.

1930 *Trial—Totals of First Four Pickings.*

No. of Stools.	Row I.				Row II.			
	Treatment.	Fruits Counted.	Infested.	Percentage Infested.	Treatment.	Fruits Counted.	Infested.	Percentage Infested.
5	P_3	966	180	**18.6**	P_3	1,073	252	**23.5**
4	C	1,087	565	51.9	C	1,171	642	54.8
5	C	1,194	627	52.5	P_2	1,116	200	**17.9**
4	P_2	694	119	**17.1**	C	778	393	50.5
4	C	1,045	634	60.7	D_2	842	22	**2.6**

TABLE IV.

1930 *Trial—Totals of Fifth and Sixth Pickings.*

No. of Stools.	Row I.				Row II.			
	Treatment.	Fruits Counted.	Infested.	Percentage Infested.	Treatment.	Fruits Counted.	Infested.	Percentage Infested.
5	P_3	1,168	305	26.1	P_3	1,289	343	26.6
4	C	523	168	32.1	C	504	170	33.7
5	C	721	237	32.9	P_2	806	166	20.6
4	P_2	821	178	21.7	C	403	133	33.0
4	C	553	249	45.0	D_2	648	24	**3.7**

TABLE V.

1930 *Trial—Progress of Infestation of Sprayed compared with Adjacent Unsprayed Plots.*

Dates of Picking.	Percentage of Infestation of Fruits.								
	P_3	C	Difference.	P_2	C	Difference.	D_2	C	Difference.
10–7–30	6.7	44.5	37.8	6.9	52.5	45.6	3.8	56.1	52.3
12–7–30	16.7	61.4	44.7	15.2	61.0	45.8	2.6	59.3	56.7
15–7–30	21.9	53.6	31.7	17.1	59.4	42.3	1.9	57.9	56.0
17–7–30	23.4	51.8	28.4	19.8	53.3	33.5	2.4	54.9	52.5
22–7–30	25.2	37.6	12.4	21.4	38.6	17.2	4.1	42.2	38.1
25–7–30	29.3	22.7	—	20.7	32.9	12.2	3.5	36.6	33.1

Three sprayings of Pyrethrum (P_3) did not give a better control than two sprayings (P_2).

In addition to this spraying trial a few gallons of Pyrethrum wash (containing extract representing 1 per cent. dried flowers) were sprayed on raspberries on a hot, sunny day when adults were abundant on the flowers (May 27th). Nicotine-Soap emulsion at the rate of 10 ozs. per 100 gallons was also used.

Some beetles were not wetted but each spray caused a great many to drop. Most of those sprayed with nicotine, but far fewer of those sprayed with Pyrethrum, recovered. Two days later many dead and paralyzed beetles were found under the plants sprayed with Pyrethrum, but few could be found under those sprayed with nicotine.

Discussion of Results.

The raspberry beetle is vulnerable in the larval state and its numbers can be reduced by the application of a stomach poison to developing fruits. It has been shown (Tables I and II) that lead arsenate can considerably reduce an infestation, especially if two applications are made. However, for reasons set out below (p. 219), this wash cannot be considered as a means of control.

The proprietary Derris preparation, although it gave promising results in 1928 and apparently excellent results in 1930, nevertheless failed materially to reduce the infestation on logans in 1929. This may have been due to one or more causes, such as the use of old stock in making up the 1929 wash, possible variation in the composition of different samples, or other unknown factors. The Derris plot in the 1930 trial was admittedly on a very small scale but, on its showing, Derris preparations are certainly worth further trials and work is being continued at East Malling with these substances.

As regards the new Pyrethrum extract ; whilst it is not denied that many adults may be killed by it, the fact that as good control was obtained by two sprayings (omitting the early application) as by three strongly suggests that the wash had a marked toxic effect on the young larvæ. It was not found possible to estimate the incidence of eggs on various plots, but they were found in numbers on all plots, indicating that they may be laid by beetles before succumbing to the effect of the sprays, or arriving after the sprays have lost their effectiveness against the adults.

Better results could possibly be obtained by two sprayings if the second spraying were carried out at a later stage than in the 1930 trial, and in further trials an attempt will be made to find optimum dates for sprayings.

At present Pyrethrum washes are somewhat expensive for regular commercial use, but the possibility of obtaining satisfactory control by two sprayings only would bring them more within the limits of commercial practice.

The cost of spray materials alone, used on loganberries at the rate of $\frac{1}{3}$ to $\frac{1}{2}$ gallon of spray per bush works out at about $1\frac{3}{4}$d. per bush per application for Pyrethrum, and rather less than $\frac{3}{4}$d. for the proprietary Derris preparation.

Dangers of Using Lead Arsenate.

The possible effects of sprays on bees has received some attention in connection with loganberry spraying, but little mention has hitherto been made of poisonous deposits on raspberries and loganberries offered for sale as food, although the fact that arsenical deposits are sometimes found on imported apples has received much publicity.

With a view, therefore, to ascertaining whether a dangerous deposit of arsenic is left on the fruits as a result of spraying with arsenate of lead, samples of loganberries so treated in the 1929 trial were sent to the Kent County Analyst, Mr. F. W. F. Arnaud, F.I.C., who kindly carried out analyses.

The result of his examinations was as follows :

Sample No.	Date of Picking.	Grains of arsenic per pound of fruit.
1	July 22nd	$\frac{1}{10}$
2	July 29th	$\frac{1}{14}$
3	August 8th	$\frac{1}{50}$
4	August 14th	$\frac{1}{200}$

Mr. Arnaud states that the maximum quantity of arsenic permissible is $\frac{1}{100}$ grain per pound of fruit. Thus the amount of arsenic was excessive in each of the first three pickings. No doubt the lack of rain in 1929 between the dates of spraying and picking was a contributory cause of the retention by the fruit of so large a deposit, but the danger of arsenical spraying cannot be too strongly emphasized.

A very heavy deposit was also left on many of the leaves and persisted throughout the picking period. A sample of such leaves taken on July 29th contained the extraordinary amount of 5.2 grains of arsenic per pound.

The third and fourth pickings of fruit were also examined for the presence of lead ; the third picking contained $\frac{1}{20}$ grain per pound, and the fourth picking none.

It is apparent that the danger of using lead arsenate on loganberries is very great and must be considered sufficient to debar its use.

A Method for Removing Larvæ from Loganberries and Raspberries.

It is often found impossible to bottle loganberries and raspberries because of the presence of beetle larvæ. During the process of bottling these larvæ leave the fruits and are killed by the heat, becoming distended as they die. They

remain white and do not take on the red colour of the fruit and are thus very conspicuous in the juice.

This can be avoided by previously washing the fruit in a weak salt solution (about 4 ozs. of salt to a gallon of water). The secret of success is to use a large enough vessel, such as an enamelled bowl or a bath, and plenty of salt solution.

The infested fruits should be poured into the liquid and lightly stirred from time to time. There should be sufficient room for the fruits to move about easily.

The larvæ leave the fruits and gradually sink to the bottom and the fruits which are so badly damaged by the pest that they are partially dried up will float to the top. After skimming off the useless fruit the rest can be lifted out by hand and dropped into a vessel of clean water. The larvæ are left as sediment in the salt solution.

About fifteen minutes in the salt solution will suffice and a few minutes in clean water will remove most of the salt. The very slight trace of salt which may remain is not objectionable and serves to improve the flavour of fruit used for jam.

Most of the maggoty fruit from the 1930 spraying trial described above was used for jam. The writer treated a sample of eight pounds of very ripe loganberries (each fruit of which contained a larva) by this method and the fruit was then made into jam. So successfully were the larvæ removed that only five were discovered in the scum when the jam was being boiled. Although the fruit was very ripe the amount of juice lost was negligible, and the jam was of excellent quality.

Maggoty raspberries and loganberries can certainly be made into good jam by this method, and there seems to be no reason why such fruit could not be successfully bottled. The writer believes that some such method is in use in commercial canning.

Summary.

The life history of, and damage done by, the raspberry and loganberry beetle (*Byturus tomentosus* F.) are briefly described and the various measures which from time to time have been recommended for this pest are discussed.

Investigations in progress at East Malling Research Station are described, including attempts to control the pest with various sprays.

Attention is drawn to the dangers of using arsenate of lead owing to the residue of arsenic on the fruits, although the pest can be reduced considerably by its use.

Trials of a new extract of Pyrethrum and a proprietary Derris preparation are shown to indicate promising lines of investigation.

A method of removing larvæ from ripe fruits, suitable for home canning and bottling, is described.

FIG. 1.

Egg of *Byturus tomentosus* F. attached to styles at apex of young raspberry fruit. Magnified.

FIG. 2.

Pupa of *Byturus tomentosus* F. Magnified.

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